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A LABORATORY GUIDE IN PHYSIOLOGY

BY

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CHICAGO.

WITH APPENDICES ON ORGANIZATION AND EQUIPMENT.

TWO COLORED PLATES
AND
SIXTY ILLUSTRATIONS.

CHICAGO MEDICAL BOOK CO.,
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PREFACE.

American laboratories of physiology have usually been established in medical schools after these institutions have already associated histology with pathology, and physiological chemistry with general chemistry. The problems presented in those American laboratories of physiology, which are departments of medical schools, are, therefore, essentially the physical problems of physiology. And such are the problems which occupy the major part of this manual. The student who has but four years to devote to the study of medicine cannot consistently be assigned more than 100 hours to 120 hours of laboratory work in physical physiology. How to most profitably spend this brief period is a question which has engaged the attention of the writer for a number of years.

In the choice of the work to be assigned to the student it has been taken for granted that he has entered upon his study of medicine with a working knowledge of physics and of Algebra, and that laboratory work in physiology is not begun until the student has made considerable progress in gross and minute anatomy. Courses in anatomy and physiology should be so coördinated as to enable the student to gain a thorough knowledge of the morphology of an organ before he experiments upon its function.

The method of presentation is purely *inductive*. The student is given the technique and, through a series of questions, he is guided in his observations. He is not, however, told what he is expected to observe, nor is he told

what his conclusions are expected to be. On these points he is left on his own resources. Repeated trial of this method with different classes proves it to be most satisfactory both to the instructor and to the student. It gives to both free play for originality and individuality.

The manual as here presented is far from complete. Should a second edition be justified, it will contain in addition to the present matter, chapters on *Metabolism and Animal Heat; Excretion*; *The Voice and Hearing; The Central Nervous System;* and, *An Introduction to Physiological Psychology.*

The Author acknowledges his indebtedness to the Chicago Laboratory Supply Co. and to Richards & Co. for the cuts used in Appendix C. He takes this opportunity to express his thanks to Dr. W. K. Jaques for preparing the chapter on Physiological Hæmatology, and to Mrs. Jaques for illustrating the same; to Dr. H. M. Richter for the chapter on Pharmacology; to Dr. A. M. Hall for the lessons on Normal Ophthalmoscopy and Skiascopy; and to Miss N. S. Hall for the illustrations of the first six chapters.

THE AUTHOR.

CHICAGO, Sept. 30, 1897.

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INTRODUCTION.

THE METHOD OF PRESENTING THE SUBJECT.

REGARDING ILLUSTRATIONS.

The profuse illustration of a text-book is in perfect accord with the principles of pedagogy; that the profuse illustration of a laboratory manual is the reverse is evident from the following considerations:

The laboratory student receives from the demonstrator the material with which he is to work. If he receives a piece of apparatus which is new to him, a few questions or hints in his laboratory manual will lead him to discover, from an examination of the *apparatus itself*, the physical and mechanical principles involved and utilized in it. Most students will spontaneously make drawings showing the essential parts of the instruments; all students will willingly do so if required. This is a most valuable exercise for the pupil, which is likely to be omitted if the manual contains cuts of the apparatus.

Nearly every exercise requires the preparation of some simple appliance—e. g., a frog board or a recording lever—whose construction will be much facilitated if the student is guided by a figure in his manual, but a model which the demonstrator has made will be a better guide.

I have often seen students read their text descriptive of some organ—e. g., a frog-heart—and verify its statements from the accompanying figures, leaving almost unnoticed the *object itself*, which lay before them. A few brief questions or hints would have led them to discover

from the object all of its essential features. Diagrammatic anatomical figures are sometimes useful in a laboratory manual, but true anatomical figures are worse than useless—they bar the student's independent progress. If his laboratory manual contains illustrations of all apparatus and tissues, and of such experiments as admit of graphic records, the student makes similar drawings in his notes, either unwillingly or dependently—frequently both. The laboratory work is thus robbed of much of the benefit it is intended to give the student. Independence and originality are completely defeated or aborted, except in the case of the rare student.

If the laboratory manual contains graphic records of experiments, much of the time of the demonstrator will be consumed in explaining to the students individually why the same physiological functions observed with slightly different apparatus and under slightly different circumstances, may yield tracings which differ in minor detail from those in the book. The energies of both demonstrator and students will thus be partially diverted from their legitimate channel.

If there are no tracings in the text, students will naturally, by comparison of their tracings, discover the essential and the nonessential features and will seek the cause of the essential features of their tracings. After the student has made these independent discoveries he is in a position to gain the maximum profit from the comparison of his own tracings with those which others have taken, and from any explanations which the demonstrator may choose to add.

It is evident then, that, from a pedagogical standpoint, the laboratory guide should be sparsely illustrated. On the other hand, the student's notes should be profusely illustrated.

REGARDING EXPLANATIONS.

What has been said regarding the illustrations of apparatus and of results applies, in principle, to the explanation of physiological observations. As wheat is more valuable than chaff, so is the independent discovery of a principle by the student more valuable to him than its explanation by a book or instructor. If the facts to be observed and the principle involved be detailed and explained in advance, the student's power of independent observation and investigation remains undeveloped.

THE FUNCTION OF THE DEMONSTRATOR.

It may be well to introduce this topic by a statement of what the function of the demonstrator is not. It certainly is not to rob the student of the pleasure, exhilaration and benefit of the independent investigation of a problem by introducing each laboratory period with an enumeration of the facts and principles which the work of the day is expected to establish. Such an introduction is worse than useless. The desirability of even asking the attention of the entire class to introductory remarks on the general bearing of the problem in hand is to be questioned. If the problem is well chosen and the work in the physiological laboratory properly coödinated with that in the recitation room and lecture room and that in other departments, its significance will at once be evident to the intelligent pupil. If the introductory talk is omitted the prompt student may begin at once, upon entering the laboratory, the problem of the day, and will have a clear gain of ten to twenty minutes. Any supplementary instruction or hint may most profitably and ecomically be written upon the blackboard.

Most of the experiments given in this book cannot conveniently be performed by one individual working alone.

After some experimentation it has been found most advantageous to divide the class into sections not exceeding thirty students, and to subdivide these sections into divisions of three students each. Each division is assigned a table. The assistant demonstrator places the material needed for any day's work either upon the table or where it is readily accessible.

Nothing should be done for the student which he can profitably do for himself. A small class with less limited time may easily construct much apparatus in the workshop. No class is so large as to debar the members from the privilege of constructing frog boards, tracing levers, etc., (which may be done at the tables) and of setting up, adjusting and readjusting all apparatus.

Nothing should be told a student which he can readily find out for himself. The function of the demonstrator is to guide the student by questions and by hints to discover facts and to formulate principles. Extended explanations on the part of the demonstrator may instruct the student, but they do not educate him.

HINTS TO THE STUDENTS.

It is a general principle that a student gets out of a course what he puts into it, and with interest. If he invests (1) intellectual capacity, (2) the spirit of inquiry and investigation, (3) the power of logical reasoning, and (4) the power to formulate conclusions; he will promptly receive interest upon the investment. Further, the greater the investment the greater the rate of interest. This may seem inequitable, but it is inevitable.

The value of taking full notes of laboratory experiments is unquestionable. The following hints regarding note taking may be advantageous:

1. Make a careful description of each new instrument with which you work.

2. Formulate each problem definitely.
3. Describe the means used in the solution of the problem.
4. Enumerate the facts observed through the help of the means employed.
5. Seek for and note causes and inter relations or the facts as far as possible.
6. Differentiate the essential from the incidental.
7. Formulate conclusions from the collected data.
8. Make generalizations as far as they are justifiable.

A good note book should possess the following qualities:

a. It should be complete, containing an account of every problem studied.

b. It should be full, containing a sufficient amount to guide another in performing the same experiments and in verifying the facts and conclusions noted.

c. It should be logically arranged.

d. It should be as neat and artistic as the student can make it in the time which he can devote to it.

PART I.

GENERAL PHYSIOLOGY OF CONTRACTILE AND IRRITABLE TISSUES.

A. THE GENERAL PHYSIOLOGY OF CILIARY MOTION.

I. a. Normal ciliary motion. b. Ciliary motion modified by the influence of narcotics and stimulants.

a. Normal ciliary motion.

1. *Appliances.*—Microscope, cell slide and cover glass; normal saline solution (NaCl 0.6 %, Appendix A, 1); physiological operating case (App. A, 3); filter paper; frog or fresh water clam or mussel.
2. *Preparation.*—If a lamellibranch be used one need only snip off, with the small scissors, a bit of the margin of a gill and mount it in a drop of normal saline solution on a cover slip, invert the cover over the cell of the cell slide and focus under low power. If a frog be used it will be necessary to pith it as a preliminary step.
3. *Operations.*—*To pith a frog.*

   (1). Grasp it with the left hand, holding the legs extended, one on either side of the little finger in such a way as to bring the dorsum of the frog toward the palm of the hand.

   (2). With the thumb and index finger fix the frog's nose and press it ventrally.

   (3). Place the point of a narrow bladed scalpel in the median-dorsal line over the space between the occiput and atlas, i. e., over the occipito-atlantal membrane. This point is most readily located by using the eyes as a landmark. *The occipito-atlantal membrane lies at the apex of an equilateral triangle whose base has its extremities in the center of the corneæ.* Having located the point for incision, press the

knife through the skin, the intervening connective tissue and the occipito-atlantal membrane, and cut the spinal cord transverely. Withdraw the knife.

(4) Insert the apex of a slender probe or of a blunt needle into the incision, turning it sharply forward so as to enter the cranial cavity. By sweeping the distal end of the probe from side to side the contents of the cranial cavity may be functionally destroyed. When it is required simply to pith a frog it is understood that the operation is complete as described above. It may, however, frequently be necessary to destroy the spinal cord as well as the brain. To accomplish this insert the needle as described under (4); but turn the point of the probe so that it shall enter the neural canal of the vertebræ. Pass it along this canal to a point nearly opposite the anterior end of the ilia. Withdraw the probe.

A pithed frog can suffer no pain, but will respond reflexly to certain stimuli. A pithed frog whose spinal cord is destroyed cannot with the skeletal muscles respond reflexly to any stimuli. Having pithed the frog and destroyed its spinal cord, pin it to a frog board with dorsum down, and legs extended.

To remove the œsophagus of a frog.

(1) Place the head of the frog nearer to the operator. With forceps lift the mandible and with the stronger scissors sever the whole floor of the mouth transversely and as far posteriorly as possible. Divide the skin in the median line as far posteriorly as the pubes.

(2) Separate the two lateral halves of the sternum by dividing the median sternal cartilage and carry the

incision through the xiphoid appendix and abdominal walls. Withdraw the pins which fix the anterior extremities; separate the lateral halves of the sternum by lateral traction upon the legs.

(3) With the forceps grasp a fold of the mucous membrane which surrounds the puckered anterior end of the œsophagus. While making gentle traction with the forceps, make, with the fine scissors, a circular incision through the mucous membrane surrounding the opening of the œsophagus.

(4) Grasp the pyloric end of the stomach; sever the duodenum; lift the stomach up vertically above the sternum; make moderate traction. The delicate and elastic submucosa about the end of the œsophagus will yield to the traction and the whole œsophagus will be readily separated from the surrounding tissues and wholly removed from the frog.

(5) Open stomach and œsophagus by means of a longitudinal incision through their walls; stretch them upon a cork board, fixing with pins, and wash off mucus with normal saline solution and camel's hair brush. Remove the excess of liquid with the help of filter paper.

4. *Observations.*

(1) Place a small piece of cork upon the anterior end of the œsophagus. Does the cork move? If so, in what direction and at what rate?

(2) Will the cork pass over the boundary line between œsophagus and stomach, and will it move over the surface of the stomach?

(3) To determine the cause for the movement of the cork, cut a minute portion of mucous membrane from the crest of one of the folds, place it in a drop of saline solution as directed under 2 [*Preparation*]

and examine with a microscope. If the preparation has been properly made the margin of the tissue should, at certain points, show the cause for the phenomena above observed. Study the character of the ciliary movements. Describe.

(4) Study ciliary movement with higher power. It is probable that the first preparation is not suited to observation with a high power. If the cilia cannot be readily brought into focus, prepare a second one as follows: From the ciliated surface—clam-gill or frog œsophagus—scrape a few epithelial cells, with the point of a scalpel, place the minute bit of tissue upon a cover glass; add a small drop of saline solution; gently tease the tissue with needles, invert the cover upon a slide, allowing one edge to rest upon a hair, to avoid undue pressure upon the tissue.

Focus under high power (300-600 diam.). If the preparation is successful groups of ciliated cells may be seen and the character of the ciliary movement studied.

b. Ciliary motion modified by the influence of narcotics and stimulants.

1. *Appliances.*—In addition to the appliances enumerated above under **a**, one needs : A gas flask and siphon as shown in Fig. 1. Also a cell slide with conducting tube. (Fig. 1 B.) A gas generator will be necessary unless there is a large generator for general use by the class. HCl 25%, marble, chloroform, ether, absolute alcohol, sealing wax, thread, small glass tube, soft parafin.

2. *Preparation.—To prepare a cell slide with conductor.*

(1) From a hard rubber ring, having an inside diameter of about 1 cm, and a thickness of about

2 mm., cut a radial segment about 2 mm. wide.

(2) Clean the ring and slide with absolute alcohol.

(3) Fix the ring to the slide with sealing wax, placing the opening in the ring toward one end of the slide.

(4) Heat the glass tube and draw it to one-half of its orginal diameter as shown in Fig. 1. B.

(5) Fix the glass tube to the slide, using sealing wax. The tube may be further supported by a few turns of heavy linen thread drawn tightly, tied and fixed in position with drops of melted wax.

(6) In order not to give too free vent from the cell for

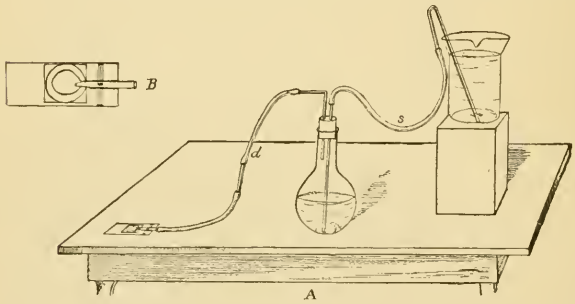


FIG. 1.

FIG. 1. Apparatus for forcing a stream of gas or vapor through a cell. For description, see **I=b** *2* and *3*.

the gas which enters by the tube a bit of soft parafin may be warmed in the hand and worked, with the point of a scalpel, into the space around the end of the glass tube leaving only a little furrow in the parafin above the tube.

3. *Operation.*—Fill the gas flask full of water and displace it with CO_2 gas. Fill the siphon and adjust apparatus as shown in the figure. During any readjustments of the apparatus the siphon may be kept

filled and ready for action by putting on a screw-clamp at *s*. Through varying the height of the receptacle into which the siphon dips or through adjustment of the screw clamp or of the spring clamp at *d*, the pressure and the rate of flow of gas are under perfect control. Prepare a specimen of cilia for observation with a low power microscope. Bring a good specimen into the field, focus the microscope and observe the rate and character of ciliary movement. Remove screw clamp at s.

4. *Observations.—a. The effect of CO_2 upon ciliary activity.*

(1) While observing closely the normal action of the cilia, press the spring clamp gently for a few moments. If after a half minute or more no noticeable change takes place in the rate of movement of the cilia repeat the dose of gas.

What is the effect of CO_2 gas upon the activity of cilia?

(2) After the effect of the gas has become apparent, clamp the tube at *d;* disjoin at glass tube beyond and gently draw air through the cell, thus ventilating it and restoring practically the normal condition. Do the cilia resume the normal movement?

(3) How many times may the cilia be narcotized to the point of complete cessation of activity and then by ventilation be revived again?

b. The effect of chloroform gas upon ciliary activity.

(4) Clamp tube at *s*; remove flask from apparatus, fill flask with water to expel CO_2; empty; drop into the flask a pledget of cotton saturated with chloroform, replace flask as in Fig. 1. Make a new preparation of cilia and observe normal movement.

Allow the chloroform gas to flow for a moment

into the cell. Note the effect of chloroform upon ciliary activity.

(5) How many times may the cilia be narcotized with chloroform and revived again through ventilation?

(6) Repeat (4) with ether in place of chloroform.

(7) Repeat (5) with ether in place of chloroform.

c. Determine the action of alcohol vapor upon cilia.

II. To determine the amount of work done by cilia.

1. *Appliances.*—Physiological operating case; frog board; cork board 10 cm. long by 5 wide; a centimeter rule; a block of wood 4 or 5 cm. in height; a bit of sheet lead 1 mm. thick; scales correct to a milligram should be accessible to the student.

2. *Preparation.*—Pith a frog and destroy cord. Dissect out œsophagus and stomach as directed in lesson I. Fix to cork board so that the long axis of the œsophagus shall be parallel with the long axis of the board. Cut a piece of sheet lead just 5 mm. square and another 3 mm. square. Weigh each of them.

3. *Operation.*—Wash off ciliated surface, remove the surplus moisture with filter paper, and place the lead gently upon the anterior end of the œsophagus.

   The incline of the ciliated surface may be changed by resting it, at different angles, against the block of wood as shown in Fig. 2.

4. *Observations.*

   (1) If the preparation is successful the piece of metal will be slowly carried up the incline. Should it fail a thinner piece of lead or a new preparation may succeed. With a given incline, is the small piece of lead carried more rapidly than the large piece?

   (2) If W = work done, g = weight in milligrams and h = height in millimeters, then $W = g \times h$ would give the work in milligram-millimeters.

   (3) Determine the distance through which the weight is carried in a unit of time [one minute is a con-

venient unit of time to use], when the incline is placed as shown in the figure.

(4) With the apparatus so adjusted what is the value of h when the distance which the weight moves is 1 cm.?

Does the thickness of the cork board need to be considered?

(5) What is the work per minute, expressed in milligramm-millimeters?

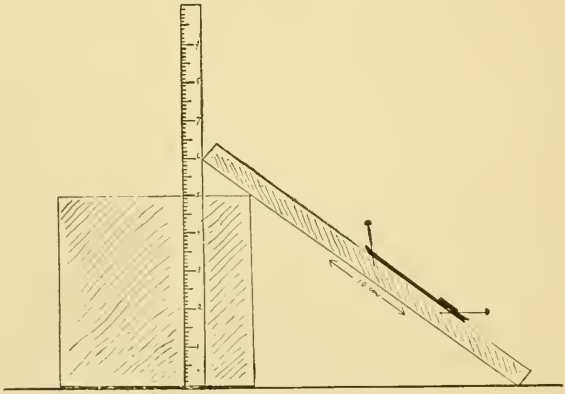


FIG. 2.

FIG. 2. Appliances for changing the angle of inclination of the ciliated tissue.

(6) What is the work done expressed in ergs? [1 erg = 1 dyne × 1 centimeter; 1 dyne = 1 gramme ÷ 981]

(7) Using the same incline compare the result in work done per minute with the two different weights? Account for the results?

(8) Using the weight which gave the larger values in the foregoing experiments, find the degree of incline which will yield the greatest amount of work?

(9) What significance has the variation of the thickness of the lead weight? Determine the upper limit of thickness?

(10) Would it be possible to determine the amount of work accomplished by each cilium? By each stroke of a cilium?

B. THE GENERAL PHYSIOLOGY OF MUSCLE AND NERVE TISSUE.

III. Demonstration: a, Elements and conductors; b, Keys; c, The commutator; d, Work done; e, Electrical units.

The function of muscle tissue is to contract. Skeletal muscles contract only in response to stimuli. Stimuli may act upon the muscle tissue—*direct stimulation*—or upon the motor nerve which supplies the muscle—*indirect stimulation*. To study the functions of muscle and nerve tissue one requires to have at command various methods of stimulation. It is usual to apply mechanical, thermal, chemical and electrical stimulation. Experience has shown that of all these means electricity is the most valuable, because it is subject to the greatest number of variations in strength and in method of application. Before entering upon a study of the responses of irritable tissues to electrical stimuli it is essential to make a short study of the appliances used. As many of these appliances have been used by the student in the physical laboratory it will be taken for granted that he is familiar with the principles involved in their use.

1. *Appliances.*—2 Daniell elements or cells; wires; contact key; Du Bois Reymond key; mercury key; commuta-

tor; sulphuric acid, 10%; copper sulphate. saturated solution; mercury.

2. *Experiments and Observations.*

a. The Daniell cell.—Present the four parts of the cell. Half fill the outer receptable of the cell with the saturated copper sulphate solution. Put the copper plate into the cell; half fill the porous cup with the dilute sulphuric acid, lower the zinc plate carefully into the cup. The plate is of commercial zinc with its various impurities.

(1) Observe the vigorous chemical action in porous cup. Write the reaction. It is evident that the zinc will be quickly consumed if allowed to remain in the acid and this will be the case whether or not the cup and zinc plate be made a part of an electric cell, and whether the cell be acting or resting.

(2) *The amalgamation of the zinc.* [See also App. A.–4.] Lift the zinc plate out of the acid, dip it into the mercury. The mercury adheres to the zinc, mingles with the surface layer of zinc, forming an alloy, with a brush or an old cloth one may rub the mercury over the whole surface of the zinc plate—the zinc is *amalgamated.* The impurities of the zinc do not enter into the alloy. In this way only the pure zinc which forms a part of the alloy is presented to the acid. Chemically pure zinc is acted upon very slowly by 10% sulphuric acid; join a wire to the exposed end of each plate. Touch the tongue with the freed end of each wire separately; touch the tongue with both wires simultaneously. Record results.

(3) Place the porous cup with the zinc plate in the receptacle holding the $CuSO_4$ with the copper

plate. Touch the tongue with one wire, then with the other. Touch the tongue with both at once. Bring the two free ends of the wires into contact with the binding posts of a detector; note results. Touch the ends of the wires together, if the conditions are favorable a minute spark may be seen on touching and on separating the two poles. What conclusions are to be drawn?

(4) Define element or cell as used in this connection. Define plate, pole, electrode. The zinc is arbitrarily taken as the positive plate and the copper as the negative plate. The pole which is attached to the negative plate is the positive pole, and that which is attached to the positive plate is the negative pole. The positive pole or electrode of a galvanic cell or of a battery is called the anode, while the negative pole or electrode of a cell or of a battery is called the kathode.

b. Keys.—(1) Show and describe the simple contact key (Fig. 7 k), the mercury key (Fig. 3), and the Du Bois-Reymond key (Fig. 4).

(2) Two ways of using the Du Bois Reymond key.
1st. As a simple contact key (Pl. I Fig 1.)
2d. As a short circuiting key (Pl. I Fig. 2.)

c. The commutator.—Most convenient for the physiological laboratory is Pohl's commutator (Fig. 5). This instrument may be used for the following purposes:

(1) *To change the direction of the current.* Set up apparatus with cross bars in place as shown in Pl. I Fig. 3. Which is the anode when the bridge is turned toward a b? Which is the anode when the bridge is turned toward c d?

(2) *To change the course of the current.* Set up apparatus with cross bars removed, as shown in Pl. I Fig. 4. What course will the current take when the bridge is turned toward a, b? What course when the bridge is turned toward c, d?

(3) Pohl's commutator may be used as a simple mercury key (Pl. I Fig. 5). Is the current open

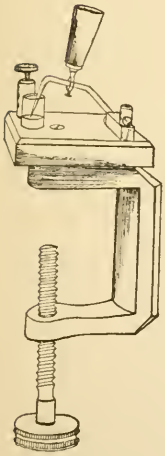


FIG. 3.

FIG. 3. The mercury key.

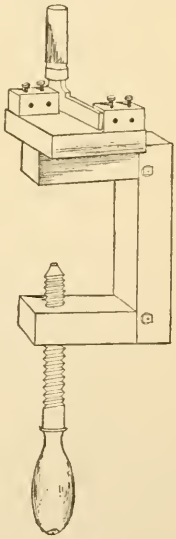


FIG. 4.

FIG. 4. The DuBois-Reymond key.

or closed when the commutator bridge is turned toward a? How may the current be opened or broken?

d. Work done by the cell.—The experiments performed show that the galvanic cell may under proper conditions, liberate energy. This energy is called elec tricity. But the immediate source of the particular

electric energy liberated in the foregoing experiments is the latent chemical energy represented in the plates and liquids of the cell.

Under the conditions produced in the working galvanic cell the latent chemical energy is transformed, and at the same time liberated as electric energy. This liberated electric energy may make itself manifest in the contact spark, in moving the detector needle or in lifting the armature of a magnet. In the last case mentioned it would not be difficult to determine the amount of work done, though it might be somewhat difficult to determine the amount of work which a cell is capable of per-

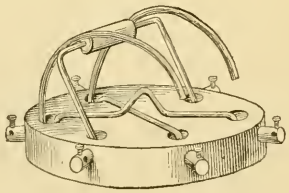


FIG 5.

FIG. 5. Pohl's commutator. For description and uses see **III=c.**

forming in a given time. If one were to weigh the copper plate before and after using the cell, one would find that it had increased in weight. This increase in weight is an index of the amount of chemical action in the cell—of the latent chemical energy which has been transformed into electric energy. It must be, then, at least an approximate index of the electric energy liberated. An exact index of the amount of current is afforded by the amount of electrolysis. For example, if the negative pole of a cell be attached to a silver or platinum

cup containing pure nitrate of silver, and the positive pole be attached to a piece of pure silver which is immersed in the silver nitrate solution, it will be found that one ampere of current will uniformly deposit 0.001118 gm. of silver upon the cup in one second of time. This brings us to the question of the units of electrical measurements.

e. Electrical units.—The electrical energy available at any point in a circuit, *i. e.*, the *current*, as it is called, is, according to Ohm's law, equal to the liberated energy—the electromotive force—divided by the total resistance of the circuit. This is expressed in Ohm's formula, $C = \frac{E.M.F.}{R}$ $C = \frac{E}{R}$ It is impossible for the physicist to make any progress in the study of electrical energy without arbitrarily assuming units of measurement for current, for electromotive force and for resistance.

(1) *Current* is measured in *amperes*. A current of one ampere deposits upon the negative electrode of a galvanic cell or battery 0.001118 gm. of silver per second, or 4.025 gm. per hour. [See above]

A concrete idea of the ampere may be gained from the fact that the small sized Daniell cell produces a current of about ¼ ampere when the external resistance is reduced to a minimum.

(2) *Resistance* is measured in *ohms*. An ohm is that amount of resistance, opposed to the transmission of electrical energy, by a column of mercury 1 sq. mm. in cross section and 106.3 cm. in length. For general purposes an ohm resistance is that of a pure silver wire 1 mm. in diameter and 1 meter in length.

(3) *Electromotive force* is measured in *volts*.

A volt is that amount of electrical energy which

will produce 1 ampere of current after overcoming 1 ohm of resistance.

"The ohm, the ampere and the volt are thus closely related, and if any two of them be known with reference to any particular electric circuit or portion of a circuit the value of the third may be readily inferred."—[Daniell]. For if $C=\frac{E}{R}$ then $E=C\times R$ and $R=\frac{E}{C}$. The same relations may be expressed thus: 1 ampere current $=\frac{1\text{ Volt E. M. F.}}{1\text{ Ohm Resistance.}}$ or 1 ampere $=\frac{1\text{ Volt}}{1\text{Ohm}}$

Therefore (1) Volts = Amperes × Ohms.

(2) Amperes = Volts ÷ Ohms,

(3) Ohms = Volts ÷ Amperes.

The small Daniell cell has about 1 volt E. M. F. and 4 ohms resistance, the current from such a cell is then equal to approximately ¼ ampere.

There are numerous other units of measurement used by physicists and electricians, but for our purpose it is not necessary to review these more specialized points.

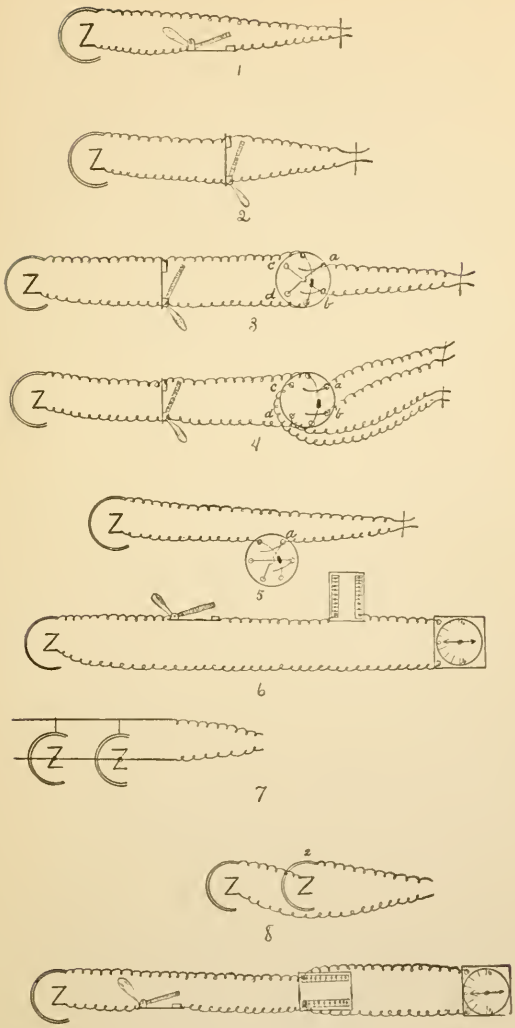


PLATE I.

IV. Demonstration: Batteries.

A battery is a group of two or more elements or cells arranged to produce increased or multiple effect. If one wishes to use a stronger current than that afforded by one cell, his first thought is to increase the number of cells, or to procure a larger cell. Experimentation will show him that it is not a matter of indifference which of these courses to pursue. In the first place if he attempts to satisfy the conditions he will find that to increase the size of the cell increases the current only when the external resistance is relatively small, and furthermore, there are practical limitations to the size of a cell and these may be much within the requirement which the cells must satisfy. It becomes apparent, then, that he who would use electrical energy beyond the most limited field must resort to a battery composed of a number of cells. The problem which first confronts him is, how shall these cells be arranged

1. *Appliances.*—6 Daniel cells; wires; detector, (Fig. 6) composed of simple magnetic needle mounted over circle divided into degrees; rheostat or resistance box, representing at least 100 ohms.

2. *Experiments and Observations.*

(1) (*a.*) Join up apparatus as shown in Pl. I., Fig. 6. With the plugs all fixed in the rheostat, i. e., with no resistance except that of the wires and battery, and the indicator needle at 0°, open the key and then observe the angle at which the needle comes to rest.

(*b.*) Remove from the rheostat the plug which will throw into the circuit an extra resistance of 10

ohms. Allow the needle to come to rest and note angle?

(*c.*) Remove from the rheostat plugs which will represent in the aggregate 100 ohms of extra resistance. Note angle of indicator as before.

(2) Join up two cells in *multiple arc* as shown in Pl. I., Fig, 7. That is, join both copper plates to one copper wire and both zinc plates to another. These wires are to be carried to key, rheostat and detector as shown in Pl. I., Fig. 6.

(*a.*) Note angle of needle with no extra resistance.

(*b.*) Note angle with 10 ohms extra resistance.

(*c.*) Note angle with 100 ohms extra resistance.

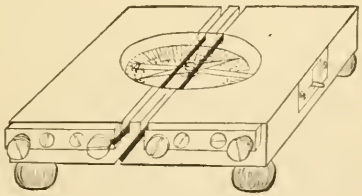


FIG. 6.

FIG. 6. Detector, composed of simple magnetic needle mounted over a graduated circle. The two heavy, copper wires which encircle the compass offer slight resistance to the electric current.

(3) Join up four cells in *multiple arc* or "*abreast*," and repeat the observations of angle at the three resistances as above.

(4) Join up six cells in multiple arc and repeat observations with 0Ω, 10Ω, and 100Ω resistance.

(5) Join up two cells *in series* as shown in Pl. I., Fig. 8. That is, join the copper of the first cell to the zinc of the second. The first cell will have a zinc uncoupled and the second will have a copper

plate uncoupled. These two uncoupled terminal plates of the battery are the ones from which to lead off the wires to the other apparatus, which should be arranged as shown in Pl. I., Fig. 6. Repeat the observations on the angle of deviation of the needle, using the 0Ω, 10Ω and 100Ω resistance as above.

(6) Join up four cells *tandem* or *in series*, and repeat the three observations.

(7) Join up six cells *in series* and repeat observations.

(8) Tabulate results and draw conclusions.

1. There is a marked difference in the results of the two methods.

2. With low external or circuit resistance the current as indicated by the angle at which the detector needle stood increased with an increase in the number of cells joined in *multiple arc or abreast.*

3. With high external resistance the strength of the current does not seem to be essentially increased by increasing the number of cells joined up *abreast.*

4. With low external resistance the strength of the current is not increased by adding cells *in series.*

5. With high external resistance the strength of current increases with an increase in the number of cells joined up *in series* or *tandem.*

The following theoretical points are worthy of note:

The general formula $C=\frac{E}{R}$ does not differentiate between that part of the resistance furnished by the battery and that part furnished by the external circuit. The former is called internal resistance (ri) and the latter is called external resistance (re). So we may write $R=ri+re$ and $C=\frac{E}{ri+re}$.

CASE I.

Suppose that the external resistance is so great in comparison with the internal resistance that the latter may be made equal to zero (ri=0) $C'=\frac{E}{ri+re} = \frac{E}{re}$ for one cell.

Suppose that we arrange a battery of sixteen cells in multiple arc. Experiment has shown that when a battery is so arranged the internal resistance of the battery decreases in proportion to the number of cells and that joining up cells in multiple arc is equivalent to simply increasing the size of the plates.

Our formula then becomes:

$$C'=\frac{E}{\frac{ri}{16}+re}\ ;\ \text{but}\ \frac{ri}{16}=0;\ C'=\frac{E}{re};\ C=C'.$$

Therefore no advantage is gained by joining up cells in multiple arc when the external resistance is incomparably greater than the internal resistance.

CASE II.

Let the internal resistance be incomparably greater than the external.

Then for one cell: $C=\frac{E}{ri+re}$; but re=0, therefore $C=\frac{E}{ri}$

Join up 16 cells in multiple arc. The internal resistance is thus decreased by the factor 16.

$$C'=\frac{E}{\frac{ri}{16}+re}\ ;\ re=0\ ;\ \text{therefore}\ C'=\frac{E}{\frac{ri}{16}}=\frac{16\,E}{ri};\ C=16C.$$

Therefore when the internal resistance is incomparably greater than the external resistance the current increases proportional with the number of cells joined in multiple arc.

CASE III.

Let the internal resistance be so small relatively as to be discarded. For one cell $C=\frac{E}{ri+re}=\frac{E}{re}$.

Join up 16 cells in series. Experiment has shown that when cells are joined in series the internal resistance increases in proportion to the number of cells, for the current must pass through all of the cells; further, the electromotive force is reinforced as it passes through each cell so that it also increases in proportion to the number of cells. Our formula then would be:

$C' = \frac{16\,E}{16ri+re}$, but $ri=0$; therefore, $C'=\frac{16\,E}{re}$; $C=16C$.

Therefore the current will increase in proportion to the number of cells joined in series, when the external resistance is incomparably greater than the internal resistance.

Case IV.

Let the internal resistance be incomparably greater than the external and join 16 cells *in series*, then:

$C'=\frac{16\,E}{16\,ri+re}$; but $re=0$; therefore $C'=\frac{16\,E}{16\,ri}=\frac{E}{ri}$.

In this case, however, $C=\frac{E}{ri}$; therefore there is no advantage gained by increasing the number of cells *in series* when the external resistance is very small.

Case V.

Practically, however, one deals with cases where neither the external nor the internal resistance is so small as to be ignored. Let us suppose that we have a battery of *a* cells, that the internal resistance of each cell is r and that the total external resistance is R. It has been shown experimentally that the current is greatest when the external resistance is equal to the internal resistance; i. e., when $\frac{s\,r}{m}=R$; s being the number of cells *in series* and m the number in *multiple arc*.

We have, then, two equations.

(1) $\frac{s\,r}{m} = R.$

(2) $s\,m = a$

Find s and m.

(3) $s = \frac{a}{m}$

(4) $s = \frac{m\,R}{r}$

(5) $\frac{a}{m} = \frac{m\,R}{r}$; or $a\,r, = m^2R.$

(6) $m = \sqrt{\frac{a\,r}{R}}$; or, in a similar way,

(6′) $s = \sqrt{\frac{a\,R}{r}}.$

Let us take a concrete case, using our 16 cells, each of which has an internal resistance of 4 ohms, how shall we arrange them to get the best results with 16 ohms external resistance.

$$m = \sqrt{\frac{a\,r}{R}} = \sqrt{\frac{16\times4}{16}} = 2.$$

$$s = \sqrt{\frac{a\,R}{r}} = \sqrt{\frac{16\times16}{4}} = 8.$$

We shall therefore arrange the battery in a *series* of 8 pairs, each pair being joined *abreast.*

How must they be arranged when there are 64 ohms or more of external resistance?

How must they be arranged when there are only 4 ohms of external resistance?

What arrangement would you adopt if there is only 1 ohm external resistance?

V. Demonstration: Methods of varying the strength of current. a. The rheostat. b. The Du Bois-Reymond rheocord.

It has already been shown that the strength of current may be varied by increasing the number of cells or by changing their arrangement in the battery. This method is indispensable, but it has its limitations. If one has a small cell and wishes to decrease the current, he must have recourse to another method. From the formula $C = \frac{E}{R}$ it is evident that one may decrease the current by increasing the resistance.

a. The rheostat.

1. *Appliances.*—Resistance box or rheostat; 1 cell; 5 wires; detector.
2. *Experiments and Observations.*

(I) Set up the apparatus as shown in Pl. I., Fig. 6.

(1) With plugs all fixed in rheostat, needle of detector at 0°, close key and note angle of deviation.

(2) Remove the plug which will throw into the circuit the lowest resistance contained in the rheostat. Note the angle.

(3) Add to the above resistance the smallest possible increment and note angle.

(4) Proceed in this way tabulating results.

(5) Conclusions.

(II) Another method of using the rheostat. The rheostat may be used in short circuit as shown in Pl. I., Fig. 9. From this arrangement of the apparatus it is apparent that when all of the plugs are in place the current will be short circuited by the rheostat. If the resistance of that part of the circuit leading to the detector —the long circuit—be considerable the long circuit

current will probably not be sufficient to cause any deviation of the detector needle; for the current varies inversely as the resistance ($C \propto \frac{1}{R}$), and if the resistance of the long circuit (R) be incomparably greater than the resistance of the short circuit (R′), then the current of the long circuit (C) will be incomparably less than the current of the short circuit (C′), i. e., $C : C' :: \frac{1}{R} : \frac{1}{R'}$, or $C : C' :: R' : R$; therefore if $R' = 0$, C must equal 0.

Suppose that the resistance of the detector circuit be only 10 ohms, and suppose we remove from the rheostat plug that represents 0.1 ohm resistance, then one-hundredth of the current will pass through the detector. If we make the resistance in the short circuit 0.2 ohms then one-fiftieth of the current will flow through the long circuit.

In this way we may increase the detector current step by step until the maximum is reached. What is the maximum current to be derived when the resistance in the long circuit equals 10 ohms, the maximum resistance of the rheostat 100 ohms, external resistance in circuit between cell and rheostat 1 ohm, E. M. F. = 1 volt, internal resistance of cell four ohms?

b. The Du Bois-Reymond Rheocord.

In the use of the rheostat the variation of the current is *step by step* and not *gradual*. Experience has shown that for certain physiological experiments it is necssary to cause a gradual variation of the current, i. e., an increase by infinitessimal increments. The Du Bois-Reymond rheocord is an instrument which fulfills this condition by adding to the short circuit millimeter by millimeter the resistance of a platinum wire. The principle and use of the Du Bois-Reymond

rheocord is the same as that of the rheostat with the exception that one ohm resistance is furnished by two platinum wires which are stretched along the top of the long resistance box. A mercury bridge makes electric connection between these wires. When the bridge or "slider" stands at 0 the conditions are the same as one has in the use of the rheostat with all of the plugs in. As the bridge is moved gradually from 0 to 100, one ohm of resistance is as gradually thrown into the short circuit. At that point a plug representing one ohm resistance may be removed and the bridge brought back to 0, and another ohm of resistance gradually introduced into the short circuit. In this way any desired amount of resistance may be introduced by infinitely small steps—by infinitessimal increments—and the current of the long circuit will be increased correspondingly.

1. *Appliances.*—1 cell; Du B-R. Rheocord; detector; 5 wires; key.
2. *Experiments and observations.*
   (1) Set up apparatus as shown in Pl. II, Fig. 1. With bridge at 0, close key and note angle.
   (2) Leaving the key closed gradually slide the bridge to 1, then slowly and with an even rate of motion on to 100, noting the behavior of the detector needle.
   (3) Open the key, remove the plug which represents 1 ohm, and slide the bridge back to the zero position, close the key and note the angle at which the needle comes to rest. If the resistance of the platinum wires is 1 ohm then the needle will come to rest at the same point noted above when the bridge stood at 100.
   (4) From this point the needle may be caused, by sliding the bridge from 0 to 100, to gradually increase its angle.

VI. Demonstration: To vary the current through the use of (a.) the simple rheocord, or (b.) the Ludwig compensator.

Besides the methods already used for varying the strength of the current one may use the *derived current*.

The simple rheocord (Fig. 7) may be used for this purpose.

a. The simple rheocord.

1. *Appliances.*—One or more cells; simple rheocord; 5 wires; detector.

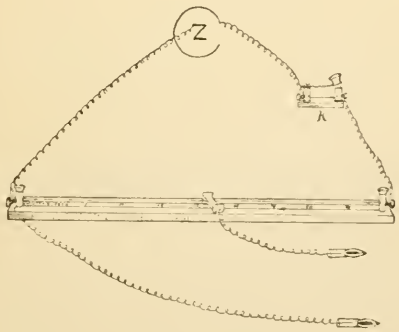


Fig. 7.

Fig. 7. The simple rheocord. See also Pl. II, Fig. 2.

2. *Experiments and observations.*

(1) set up the apparatus as shown in Fig. 2, Plate II. From the figure we see that from the cell to post A, thence through the German silver wire to post B and back to the cell makes a complete circuit. Having reached the metallic slider (S) the circuit has two paths presented. 1st, from S direct to B; 2d,

from S through D and back to B. The total current is divided into two parts, C which passes along the wire from S to B, and C′ the derived current which passes through the detector. Suppose the resistance to the last named current is R′ and that to the direct current is R, the relative strength of these two currents is expressed in the following proportion: $C' : C :: R : R'$.

But the resistance of the German silver wire may be conveniently divided into 100 equal parts (100 r).

If the slider be placed at any position along the wire, say at x centimeters from the end, then the formula would be $C' : C :: 100r - xr : R'$.

$$C' = \frac{Cr(100-x)}{R'}.$$

Suppose that R = 1 ohm (r = 0.01 ohm); R′ = 2 ohms and x = 0; i. e., suppose the slider to be hard up to A, then $C' = \frac{Cr(100-x)}{R'} = \frac{C}{2}$; or the current which passes to the detector is one-half as strong as the current through the rheocord.

(2) What is the relative strength of the two currents when x = 10?

(3) What is the relative strength of the two currents when x = 50?

(4) What is the relation of C′ to C when x = 99?

(5) What is the relation of C′ to C when x = 100?

From this course of reasoning it is evident that in the simple rheocord we have an instrument with which we can vary a derived current from zero to a maximum. Just what the value of this derived current will be will depend upon the voltage of the cell or battery and the total resistance to be overcome, as well as upon the distribution of that resistance.

(6) Verify the theory just developed, making out a table of detector readings.

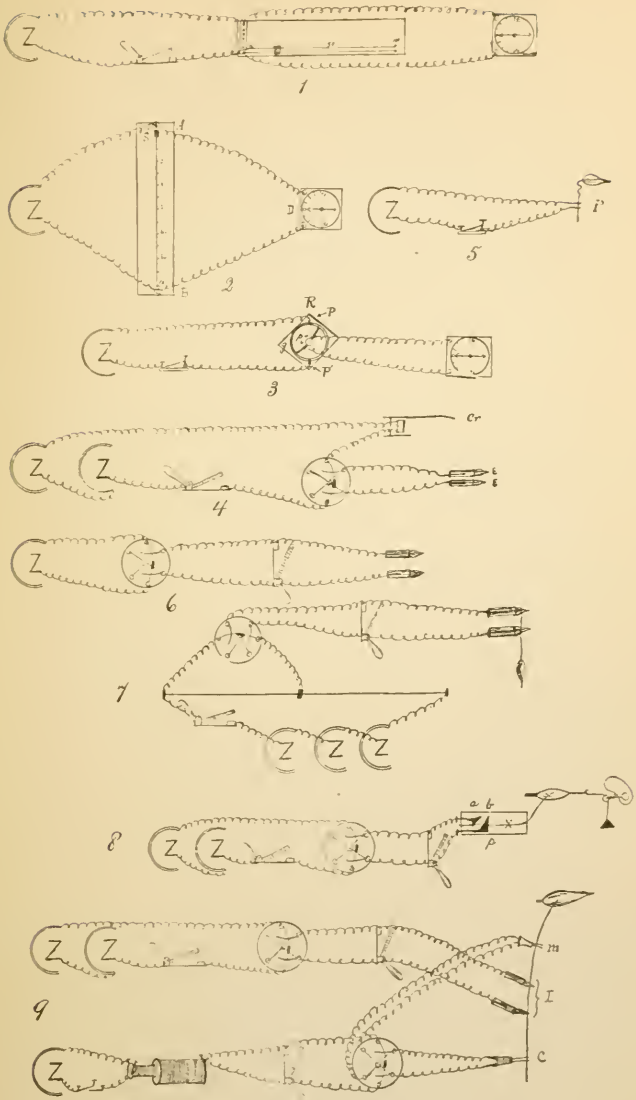


PLATE II

b. The Ludwig compensator.

This instrument, though used in a class of experiments quite different from those in which the rheocord is used, involves the same principle as that involved in the simple rheocord, and is used to make minute variation in the strength of a current. The general construction of the instrument is shown in Fig. 8.

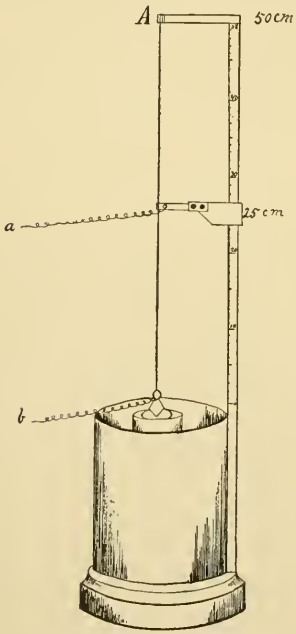


FIG. 8. The Ludwig compensator, originally devised by Ludwig to compensate a muscle current, may be used in the same way as the simple rheocord. Its maximum current is, however, limited. For description, see **VI=b.**

FIG. 8.

The outer receptacle is of copper and serves as the copper plate; within is a porous cup containing the zinc plate. This is practically a Daniell cell. A graduated upright of brass makes metallic contact with the copper plate, and at A the circuit is completed by a platinum wire to B.

A slider makes contact with the platinum wire, but slides along the standard by an ebonite arm. The derived current passing along the wires A and B, and the direct current from S to B along the platinum wire sustain a relation similar to that of currents C and C′ in the rheocord.

1. *Appliances.*—Ludwig compensator; 2 wires; detector.
2. *Theory, experiments and observation.*

(1) Join the two poles, a and b, to the detector; place the slider at 0 cm., or hard up to the zinc plate, and note the deviation of the needle.

(2) Gradually move the slider from 0 cm. to 50 cm. (or 100) noting the effect upon the needle.

(3) Suppose the detector circuit, from S through the detector and back to B, has a resistance of 10 ohms ($R' = 10$). Let the resistance of the platinum wire be 0.01 ohm per centimeter; for the instrument figured, $R = 0.5$ ohm. Let C′ be the detector current, and C the direct current. Then $C' : C :: \frac{1}{R'} : \frac{1}{R}$, or $C' : C :: R : R'$, or $C' = \frac{C\,R}{R'}$. Let x be the distance in centimeters from B to S, or the reading of the position of the slider; then the proportion of R at any position of the slider would be $\frac{x\,R}{50}$. $C' = \frac{C\,x\,R}{50\,R}$; substituting the assumed values, $C' = \frac{C\,x}{1{,}000}$.

(4) When $x = 0$ how much current will flow through the detector?

(5) When the slider stands at 10 cm. what proportion of the total current will flow through the detector?

(6) When the slider stands at 25 cm., how much larger is C than C′?

(7) When the value of x is 50 the ratio of the detector current to the direct current?

(8) Verify all of these theoretical results as far as possible, by experiment.

VII. Demonstration: To send an electric current into a nerve gradually. Fleischl's rheonom.

When one studies the effects of thermal, mechanical or chemical stimuli, he may apply the mechanical stimulus so slowly that the nerve may be severed without calling forth a response; he may apply heat to the fresh nerve so gradually that the nerve may be actually cooked without causing a contraction of the muscle which it supplies.

The problem which we have next to solve is to apply an electrical stimulus gradually.

1. *Appliances.*—Fleischl's Rheonom; 1 Daniell cell; Du Bois-Reymond's "Muscle Telegraph;" contact key; detector; saturated solution of zinc sulphate; 5 wires; frog; operating case.

   The rheonom is constructed as shown in Pl. II. Fig. 3—R. Its essential features are: g, the non-conducting base with circular groove; s, the non-conducting rotatable, central standard; P, the battery binding posts, having zinc connection with the groove; p, the rotating, binding posts, having zinc limbs connecting with the groove.

2. *Experiments and Observations.* — Set up apparatus as shown in Pl. II. Fig. 3, after amalgamating the zinc tips which dip into the zinc sulphate. Fill the groove with zinc sulphate.

   (1) Find and mark the zero position for the rotating limbs of the rheonom; i. e., find the position which will give no deviation of the detector needle when the contact key is closed.

(2) Find and mark the position which the rotating limbs occupy when the detector needle indicates 10°.

(3) Find and mark in succession each higher increment of 10° until the maximum is reached.

(4) Rotate the limbs so gradually as to cause the detector needle to rotate with slow and regular motion from the zero position to the maximum position and back.

(5) Make a gastrocnemius muscle nerve preparation; mount it in the muscle telegraph; change the wires from the detector to the electrodes of the muscle telegraph; place the limbs of the rheonom in the maximum position, close the key. With the closing of the key the maximum current is instantly thrown into the nerve and serves as a strong stimulus in response to which the muscle contracts.

(6) Place the limbs of the rheonom in the minimum position. Close the key. Inasmuch as the muscle nerve preparation is much more sensitive to electricity than is the low resistance detector the muscle will probably respond when the conditions are as above indicated. Theoretically a zero point exists. Practically it is difficult to find it for a muscle-nerve preparation. The finding of a position where there is no response on closing the key is however not essential in this experiment.

(7) Keeping the key closed, slowly rotate the limbs of the rheonom from the minimum position to the maximum position. If the conditions are favorable this can be done without calling forth a response.

(8) Without opening the key, slowly rotate the limbs backward from the maximum to the minimum position. One may thus send through a nerve a strong current and may withdraw the same without caus-

ing a contraction of the muscle. Keep the key closed.

(9) Quickly rotate the limbs from minimum to maximum; the muscle responds. Quickly rotate from maximum to minimum; the muscle responds.

From the preceding observations one may conclude that response to electrical stimulation is elicited not by the simple flow of an electric current through the irritable tissues, but by a *more or less sudden change in the strength of the current.* The opening and closing of a galvanic current, also its sudden increase or decrease, serves as an efficient stimulus, while *the gradual increase or decrease in the strength of the current causes no response.*

VIII. Demonstration: To determine the influence of the kathode and anode poles.

Many of the phenomena of muscle-nerve physiology were inexplicable until a difference was noted (Von Bezold 1860), in the influence of the anode and kathode. This difference in the influence of the two poles may be best observed by use of the sartorius muscle of a frog.

1. *Appliances.*—A double myograph and support; recording drum; Daniell cell; Pohl commutator; Du Bois-Reymond Key; nonpolarizable electrodes; 5 wires; electrode clamp and support.
2. *Preparation.*

(*a*) *Nonpolarizable electrodes.*—The Du Bois-Reymond nonpolarizable [N P] electrode is made as follows: (Fig. 9). T. Glass tube of about 4 mm. lumen. Z. Zinc rod with a binding screw (B). The zinc rod must be amalgamated before use in an electrode. R. Rubber tube clasping both glass tube and zinc rod. S. Saturated solution of sulphate of zinc, introduced with a narrow pointed pipette. C. Kaolin plug, made by working china clay powder into a stiff paste with normal salt solution.

The electrodes should be filled at each time of using, and the parts may be "assembled" in the order and manner enumerated in the description.

(*b*) *The Fleischl brush electrode* differs from the foregoing in substituting the brush of a camel's hair pencil for the kaolin plug. This variation of the N P electrode is somewhat more difficult to prepare, but is more convenient for certain uses.

(*c*) If one has not the zinc rods at hand he may readily prepare an efficient N-P electrode as follows: 1st. Take 5 cm. of No. 16 copper wire, make one end perfectly clean and bright. 2d. Dip the bright end into molten c. p. zinc. The zinc adheres to the wire, and if the dipping be repeated two or three times the lower 1 centimeter of wire will have a

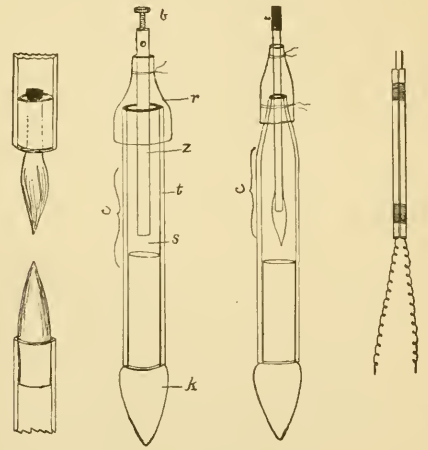


FIG. 9.

FIG. 9. Nonparizable electrodes, hand electrode.

The Du Bois-Reymond N-P electrodes, shown in the two middle cuts, are described in the text **VIII-2** (a), (c).

The Fleischl brush electrode, mentioned in the text [2 (b)], may be prepared by setting the brush in stiff kaolin paste, or if a more permanent electrode is desired, in plaster of Paris.

A plaster of Paris pencil, as shown in the lower left hand cut, may be used for ordinary work with the constant current.

The hand electrode shown at the right, is used with an induced current.

thick coating of zinc. 3d. Take a glass tube 10 cm. long, and with a 4 mm. lumen, draw it in the

middle to about two-thirds its original diameter, cut it into two such as shown in the figure. Before assembling the parts, that part of the copper wire not covered by zinc, excepting the tip (t) must be painted with brunswick black or any varnish, and the zinc must be amalgamated. With this electrode, as with the preceding, zinc sulphate, kaolin and NaCl 0.6 per cent are used. The part C in these electrodes may be held in a clamp.

d. A double myograph.

A most efficient, as well as convenient and economical double myograph may be arranged for this experiment as indicated in Fig. 10.

It will be noticed that two common muscle levers such as are shown in Fig. 13, are used, that these are held in position by common clamps and heavy support, that the upper myograph is reversed and its lever counterpoised by the weight (w), that between the two myographs a small wooden block—with a longitudinal hole for the loop of thread which holds the muscle—is held by a clamp.

3. The experiment.

(1) Curarize a frog. (See Appendix A–5.)

(2) After the lapse of three hours or more, the sartorius muscle may be prepared as described in Lesson X.

(3) Mount the preparation by passing a loop of coarse thread through the hole in the block (b), lift the muscle by its tendon of insertion, pass it through the loop, draw the loop gently around the middle of the muscle and fix by making a single knot around the screw (s) of the clamp. The fine hooks which join the muscle to the levers may now be passed through the tendons, and the proper position of the levers effected by an adjustment of the clamps. The non-polarizable electrodes may be clamped between two

pieces of cork and held by an extra support. A "universal" clamp holder is a most desirable accessory to this apparatus.

The electrical apparatus should be set up as shown in Pl. II., Fig. 4.

With this arrangement either electrode e or electrode e′ may be made the anode, the experimenter needing only to reverse the commutator bridge to reverse the position of anode and kathode.

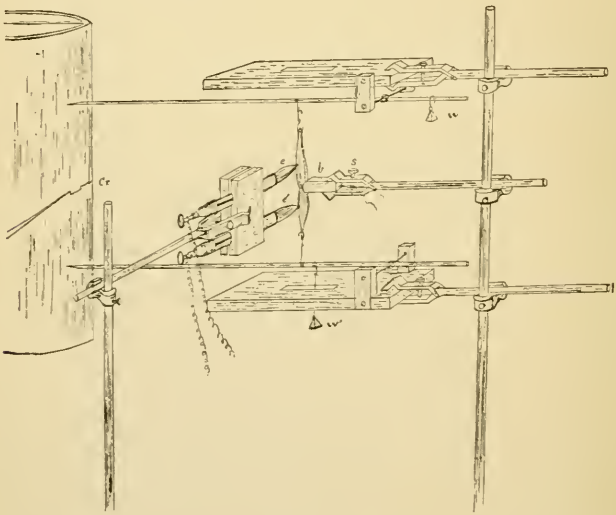


FIG. 10.

FIG. 10. Double myograph. Described in the text under **VIII**-3.

The recording drum or kymograph should rotate rapidly. The recording points of the myograph levers should be adjusted so that the point of the upper one touches the drum vertically over the point of the lower one. Adjust the time marker so that it will indicate the time of making and breaking the circuit, i. e., so that it

will record on the drum the time of making stimulus and the time of breaking stimulus. The recording point of the time marker should, of course, be in the same vertical line with the myograph points. The moist tips of the N–P electrodes should be so adjusted as to just touch the muscle above and below the loops of thread.

(1) Close the key. If the preparation has been successful, the half of the muscle in contact with the kathode pole will respond before the other one.

(2) Break the current. The anode should respond first.

(3) Reverse direction of current and repeat (1) and (2).

(4) Vary the strength of current through use of simple rheocord and determine whether the results are the same for currents of different strength.

Law I. The make-contraction starts at the kathode and the break-contraction starts at the anode, or

When irritable tissue, muscle, or nerve, is subjected to a galvanic current the response to the stimulation begins in the region of the kathode on making the current and in the region of the anode on *breaking* the current.

Would the foregoing observations justify the following statements: (1) Kathodic contractions, or make contractions, may be caused by a galvanic current which is too weak to cause anodic contractions or break contraction. (2) Kathodic or make contractions are stronger than anodic or break contractions.

IX. a. The muscle-nerve preparation. b. Indirect mechanical, thermal and chemical stimulation of the gastrocnemius.

a. The muscle-nerve preparation.

1 *Appliances.*—Frog board and pins; operating case; *glass nerve-hooks*, like Fig. 11, A, made as follows: Take a 10 cm. piece of glass rod, heat and draw in center to about 1½ mm. diameter; cool, cut in two, heat the points to smooth them and bend the end over to form the hook.

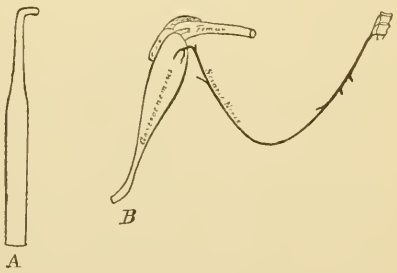


Fig. 11.

Fig 11. A Glass nerve-hook; for description see **IX-a-1**. B. Gastrocnemius muscle-nerve preparation. For description, see text **IX-a-3**.

Simple myograph or muscle lever (See Fig. 13). Watch glass with salt crystals. 20 cm. of thick copper wire.

2. *Preparation.*—Pith a frog and fix to frog board, with dorsum up.

It will be taken for granted that the student is familiar with the anatomy of the frog's leg and thigh. The ac-

companying cuts may serve to refresh the memory. (Fig 12)

3. *Operation.—To make a gastrocnemius "muscle nerve preparation."*

(1) Make, with scissors, a circular cutaneous incision around the tarsus, corresponding with the lower end of cut B. Make a longitudinal cutaneous incision, beginning at the margin of the circular incision where it crosses the external aspect of the tarsus, carry it along the tibia, along the course of the biceps femoris muscle, over the pyriformis to the posterior end



FIG. 12.

FIG. 12. Showing the muscles of the frog's thigh and leg.

of the urostyle, along the whole extent of the urostyle. From the posterior end of the urostyle make an incision posteriorly and ventrally, for 1 or 2 cm. Grasp the free margin of the skin at the point of the circular incision and with a quick traction toward the head of the frog the skin will be removed from the whole field of operation.

(2) Pass a point of the fine scissors under the glistening tendon of the biceps femoris where it is inserted

into the tibia, taking care not to injure any of the neighboring tissues. Sever the tendon. Grasp its free end, lift the biceps up, carefully cutting the delicate connective tissue which joins it to neighboring structures; sever its heads. The removal of the biceps and a separation of the cleft which the biceps occupied reveals three blood vessels and the large trunk of the sciatic nerve. Which of the blood vessels is the sciatic artery? Which the sciatic vein? Which the femoral vein?

Grasp and lift up the posterior end of the urostyle, sever the ilio-coccygeal muscles, remove the urostyle.

The sciatic plexuses formed by the 7th, 8th and 9th pairs of spinal nerves will be revealed.

(4) Pass a glass nerve hook under the sciatic nerve, gently lift it up, severing, with the scissors, the connective tissue. The pyriformis muscle must also be divided. The whole length of the sciatic nerve may thus be readily dissected out. Care should be taken not to stretch, pinch or cut the nerve during this process. Lay the nerve upon the gastrocnemius muscle.

(5) Grasp the triceps femoris muscle, pass a blade of the scissors under its tendon; sever, and remove the whole mass of muscles anterior to the femur. In a similar manner remove the muscles posterior to the femur.

(6) Grasp the tendo-achillis, sever low down at X; lift up the gastrocnemius, sever the tibia and its associated muscles as near to the knee joint as possible.

(7) Sever the femur at the juncture of its middle and upper thirds. The finished preparation has the characteristics shown in Fig. 11—B. A segment of the vertebral column may or may not be left on.

b. The indirect stimulation of the gastrocnemius.

4. *Observations.—To mount the muscle-nerve preparation* in the myograph. Fix the femur in the clamp (Fig. 13-c); place a piece of filter paper, wet with normal saline solution, upon the glass nerve support (s); lay the nerve upon the support; make a longitudinal slit in the tendo-achillis, pass the hook of the muscle lever through the slit and so adjust the height of the clamp as to bring the lever into a horizontal position.

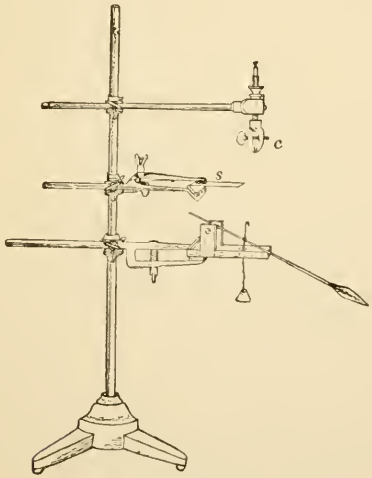


Fig. 13.

Fig. 13. Simple myograph, with a femur-clamp (*c*), and a glass plate (*s*) for a nerve rest.

a. Mechanical Stimulation.—(1) Snip off with scissors the central end of the sciatic nerve. If the muscle instantly contracts, thereby lifting the lever, the observer will know that his preparation is successful. If it does not respond to the first stimulation it may to a second or subsequent one. If it responds to

later stimuli but not to the first ones, one may conclude that in making the preparation a portion of the central end of the nerve was killed.

(2) What may one conclude if the muscle responds to stimuli applied to the central end of the sciatic nerve, but later fails to respond to stimuli applied farther along the course of the nerve, i. e., nearer the muscle?

b. Thermal Stimulation.

(3) Make and mount a fresh preparation. Heat the copper wire in a gas flame and touch the end of the nerve with the hot wire. If the preparation has been successful the muscle will respond by a contraction. If the preparation is a good one save at least ⅔ of the nerve for the subsequent experiment.

c. Chemical Stimulation.

(4) Cut off the part of the nerve which is dead and lay the central end of the still functional nerve in a saturated solution of common salt. Await results. Record all results.

X. Variation in the method of applying mechanical, thermal and chemical stimuli.

1. *Appliances.*—Operating case; kymograph; myograph; 3 frogs.

2. *Preparation.*—Much interest will be added to these experiments if a permanent record be made of the movements of the lever when the muscle responds to a stimulus. The most practical method of recording these movements is to cause the lever point to trace them upon a moving surface. It is customary to use a rotating cylinder, upon which is fixed a glazed paper which may be smoked in a gas flame. The *kymograph*—wave writer—an instrument much used for this purpose, consists of a metallic cylinder and a clock work for its propulsion (See Fig. 14.)

   Describe the structure of the kymograph giving figures.

   To prepare the kymograph for work. (See Appendix A–6.)

   To curarize a frog. (See Appendix A–5.)

3. *Operation.—To make a sartorius preparation.* After the frog has come under the influence of the curare, pass a blade of the fine scissors under the tendon of insertion of the sartorius; cut it as close to the tibia as possible; grasp the tendon with forceps and carefully lift it up, cutting, with the scissors, the connective tissue which holds the muscle in place; follow it as far as possible and get as much of the tendon of origin as possible. Mount this preparation by tying a thread to each terminal tendon, and fixing one thread to the myograph clamp and the

other to the tracing lever. This muscle should not be made to lift as heavy a weight as is used for the gastrocnemius.

4. *Observations.*

(*a*) *Direct versus indirect stimulation.*

(1) Put saturated salt solution upon the sartorius—*direct stimulation.* If it responds take a tracing of the response.

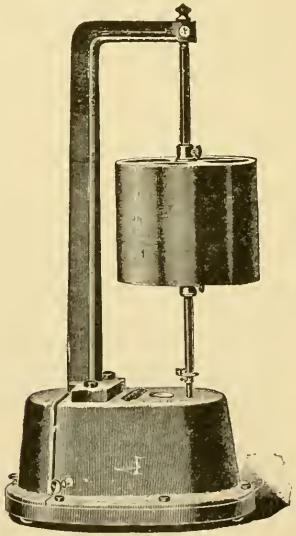


FIG. 14.

FIG. 14. The Kymograph. For description see Appendix C.

(2) Mount the second sartorius and try mechanical and thermal stimuli, tracing and recording results.

(3) Prepare and mount a gastrocnemius preparation, from a frog that was not curarized. Apply various stimuli to the nerve—*indirect stimulation*—as in the previous lesson and record results.

(*b*) *Qualitative variation of stimuli.*—Make and mount a gastrocnemius preparation for indirect stimulation.

(5) Study the response to the following variations of mechanical stimuli: cutting, pinching, tapping, pricking.

(6) Study the responses to the following variation of thermal stimuli: ice, hot wire.

(7) How does the muscle respond to indirect stimulation with glycerine, alcohol?

(*c*) *Quantitative variation of stimuli.* Use gastrocnemius preparation.

(8) Mechanical stimuli: light tapping, heavy tapping.

(9) Thermal stimuli: Touch the nerve with the wire which has been held in boiling water, i. e., 100° C.

Touch the nerve with a wire which has been heated to redness in a gas flame.

(10) Chemical stimuli: Put the end of the nerve into 0.6 % solution of common salt. Follow this with ½ saturated solution of common salt. Compare the results with those obtained when a saturated solution was used.

(*d*) *Variation in the length of time of applying stimulus.* Use gastrocnemius preparation.

(11) Cut off, or pinch off the nerve very slowly. This may be done so slowly and with such a gradual increase of pressure as to cause no contraction of the muscle.

(12) Put the central end of the sciatic into tepid 0.6 % NaCl solution, and gradually bring to a boil, protecting the muscle and that part of nerve not in the solution, with absorbent cotton moistened in normal saline solution.

The nerve may be functionally destroyed without causing a contraction of the muscle.

(13) Put the central end of the nerve into Na Cl 0.6 % and gradually add salt to saturation. Take another preparation, put the nerve into a few drops of NaCl 0.6 %. Add alcohol drop by drop until the mixture is about 90 % alcohol. Record results.

XI. Electricity as a stimulus. The galvanic current.

1. *Appliances.*—Operating case; 3, 10 cm. pieces of uncovered copper wire; a piece of zinc; beaker; a Daniell cell; kymograph; myograph; simple contact key; 4 covered battery wires; 2 frogs.
2. *Preparation.*
   (1) Curarize a frog.
   (2) *To prepare a "water element,"* take a small bright piece of zinc, wind one end of a 10 cm. piece of copper wire around it, remove the glass plate from the middle clamp of the myograph, clamp two copper wires so that one or two centimeters of wire will extend out horizontally on one side of the clamp, while the other longer ends extend out on the other side; one of these is wound around the piece of zinc. Bend these long ends down to the perpendicular. Do not allow these wires to touch each other in any part of their course.
   (3) Charge the Daniell cell (See Appendix A–4), insuring the proper amalgamation of the zinc. Do not put the zinc into the cup until the cell is to be used.
3. *Experiments and Observations.*
   (1) Take two coins of different metals, preferring copper and silver. With a knife or file brighten on the circumference of each two small surfaces removed from each other by $\frac{1}{4}$ to $\frac{1}{6}$ the circumference. Touch each coin separately to the tongue. Now bring the two coins into close contact at bright points, leaving the other two fresh surfaces in such a position that the tongue may touch both at the same time. Touch

the coins with the tongue as indicated. Is there any difference in the sensation which the tongue receives in these two experiments? Record results, accounting for phenomena.

(2) While in the operation of making a gastrocnemius preparation, after the sciatic nerve has been freed from the other structures in the thigh, slip the glass nerve-hook under it so that the handle of the nerve-hook will hold the nerve away from the other tissues. Press the end of a copper wire against the muscles of the thigh, touch the silver probe to the sciatic nerve, then to the copper wire, first separately, then simultaneously.

Vary the experiment by using other combinations: Silver and steel, copper and steel, etc. Note briefly the original observations of Galvini. Are the observations just made different in any essential respect from the observation which led to the discovery of what we call galvanic electricity?

(3) Complete the gastrocnemius preparation, mount the muscle in the myograph, place the nerve across the horizontal ends of the two wires, lift the beaker of water and immerse the two pendant plates—the copper wire and the piece of zinc.

If the experiment is successful the muscle responds vigorously. Is there any chemical action in this water element? If so, describe it. Would oxidized or tarnished plates answer as well as bright ones?

(4) Mount another gastrocnemius preparation, adjust the Daniell cell for action, set up the electric apparatus as shown in Plate II, Fig. 5, clamp the two exposed poles (p.) in the middle clamp so that the ends are exposed for about two centimeters. Place the nerve across the poles. Adjust the kymograph for tracing a myogram.

(*a*) Close the key, i. e. "make" the current, and hold the key down for several seconds. Note results and take tracing.

(*b.*) Open the key, i. e. "Break the current." Note results and take tracing.

(*c.*) Make and break the current during one rotation of the drum. If there is a response on both make and break, so time the closing and opening of the key that these will come in pairs with a considerable pause between. Before *fixing* the tracing, (see Appendix A–7.) mark each wave which was the effect of making the current *m.*, and each wave which was caused by breaking the current, *b.*

(5) Prepare and mount a sartorius from the curarized frog. Bring the two poles into contact with the muscle, and repeat the experiments suggested under (4.)

(6) In experiments (4) and (5) the observer has applied electric stimulation of medium strength both directly and indirectly to the sartorius and gastrocnemius muscles. He is justified in formulating certain conclusions—subject to subsequent modification.

Formulate conclusions.

(7) Describe minutely the chemical and physical processes going on in the active Daniell cell.

XII. Stimulation with the constant current. The simple rheocord.

1. *Appliances.*—Operating case, kymograph and myograph; 3 or 4 Daniell cells; simple rheocord; materials for making nonpolarizable electrodes, (see demonstration VIII); Pohl's commutator with cross-bars; Du Bois-Reymond key; 9 wires; 3 frogs.
2. *Preparation.*
   (1.) Make a pair of N P electrodes.
   (2.) Set up apparatus as shown in Pl. II, Fig. 6.
3. *Operation.*—Make and mount a gastrocnemius preparation and so adjust the nerve to the electrodes that the current will be a "descending" one, i. e. so that the kathode will be nearer to the muscle than is the anode
4. *Observations.*
   (1) (a) Open the short-circuiting Du Bois-Reymond key—i. e. *make* the long circuit.
   (b) Close the key, thus breaking the long circuit, or muscle-circuit.
   (c) Take a tracing of a series of alternating make and break shocks with *descending* current.
   (d) Take a tracing with ascending current. How may one change the direction of the current along the nerve without changing the adjustment of nerve and electrodes?
   (2) (a) Give the preparation a stronger stimulus by joining two cells. Should one join the cells *in series* or *multiple arc?* Why?
   (b) Take a tracing as before using the descending current.

(c) Vary the experiment by the use of the ascending current.

(3) (a) Increase further the strength of the stimulus by the use of a battery of three or four cells.

Record effect of descending current.

(b) Record effect of ascending current.

(4) Set up electrical apparatus with simple rheocord as shown in Pl. II. Fig. 7. Instead of making a tracing tabulate the results.

(a) Adjust for stimulation with the minimum descending current. *Make* the muscle circuit and record whether the muscle contracted, or remained at rest.

(b) Stimulate with minimum ascending current and record.

(c) Gradually strengthen the current, recording at each position of the slider the results for both descending and ascending currents, make and break.

The following form of table should be used:

STRENGTH OF CURRENT.	DESCENDING.		ASCENDING.	
	Make	Break.	Make.	Break.
Weak.	Contract.	Rest.	.....	.....
Medium.	.....	.....	.....	.....
Strong	.....	.....	.....	.....

(5) Sum up the day's work in a series of conclusions.

XIII. The effect of the induced current.

1. *Appliances.*—Operating case; inductorium with Neef hammer; contact key; DuBois Reymond key; 7 wires; 1 Daniell cell; materials for making hand electrodes [2 No. 24 or 28 wires ½ meter long, 2 pieces of capillary rubber tubing 4 or 5 cm. long, thread]; 2 frogs.

2. *Preparation.*—(a) *To make hand electrodes for use with induced currents.* Push a thin wire through a piece of capillary rubber tubing (capillary glass tubing may be used instead of the rubber), bring two such side by side and wrap thread around them. If glass tubing be used the wire will need to be fixed in the tubes with a drop of sealing wax.

   Such a pair of hand electrodes are shown in Figure 9, page 52.

   (*b*) Set up electric apparatus with contact key in *primary circuit* and short-circuiting key in secondary circuit.

3. *Operation.*—Make and mount gastrocnemius preparation.

4. *Observations.*

   (1) Take tracings of the contractions produced by a series of "*make, induction shocks*" applied indirectly. The "*make, induction shock*" is obtained as follows: (*a*) With primary circuit not interrupted by the Neef hammer, but closed and opened only by the contact key; open the short-circuiting key of the induced circuit.

   (*b*) Close the contact key of the primary circuit, a *make induction shock*—i. e., a shock in the in-

duced circuit caused by a closure of the battery-circuit—will stimulate the preparation.

(*c*) Close the short-circuiting key in the secondary circuit.

(*d*) Open or break the primary circuit. An induced break shock occurs in the secondary circuit but it is short-circuited by the closed Du Bois Reymond key. If while the drum rotates one makes, in close succession, the changes above indicated—a-b-c-d-a-b-c-d etc.—there will be produced a series of contractions, all the result of stimulation by *make induction shocks*.

(2) Take a tracing of the contractions resulting from a series of indirectly applied *break induction shocks*.

(3) By leaving the short-circuiting key open, one may get a series of contractions due to alternating make and break induction shocks. Let these be recorded in pairs upon the kymograph.

(4) Determine the distance which the secondary coil may be removed from the primary coil and get any response to the make or break. Which is more effective make or break? Can one find a position of the secondary coil where there are only make or break shocks? What are the limits of this position? Within the limits of that position where both make and break contractions occur are there differences in the height of the make or break waves? Is there a position of maximum height for both waves? If not, is there a position of maximum height for each wave?

Make a tracing on a slowly rotating drum, while gradually moving the secondary coil from the greatest distance which gives a contraction up to the zero point. Record at intervals upon the tracing

the positions of the secondary coil at that point in the tracing.

(5) Still leaving the short-circuiting key open make and break the primary current as rapidly as it is possible to close and open the key in the primary circuit. Take tracing.

(6) So adjust the apparatus that the Neef hammer is brought into the primary circuit, thereby making and breaking that circuit with each vibration of the hammer. Mount a fresh gastrocnemius, adjust the kymograph for slow or medium rotation.

Close the short circuiting key; close the key in the primary circuit. The Neef hammer should start to vibrating and continue to do so as long as the primary circuit is closed. Start the kymograph. After an abscissa a few centimeters in length has been traced upon the drum, open the short-circuiting key. If the experiment is successful the muscle will be *tetanized.* Allow the tetanizing current to operate until a tetanus tracing several centimeters in length has been traced. Close the short-circuiting key.

After a few moments the muscle may be again tetanized, and repeatedly so until exhausted.

XIV. The work done by a muscle. a. To determine the amount of work done by a single contraction. b. To determine the total amount of work done by a muscle. c. Reaction changes in fatigued muscle.

1. *Appliances.*—Same as in lesson XIII.; also 50-gramme weight and 20 or 30-gramme weight.
2. *Preparation.*—Arrange electrical apparatus for a series of break induction shocks.
3. *Operation.*—Make and mount a gastrocnemius preparation for indirect stimulation.
4. *Observations.*—Upon a slow drum record in close order a series of break contractions.

a. To determine the amount of work done by a single contraction.

(1) What weight is lifted?

(2) How high is it raised?

(3) What is the ratio between the height of the curve traced by the lever and the height through which the weight was raised?

(4) Let W = work done.
g = weight lifted.
h = height of curve traced by lever.
κ = *constant* of the apparatus, in this case the ratio between the lever arms. Then $W = \kappa . g . h$.

(5) Express the amount of work in *ergs*.

b. To determine total work done.

(5) How many times was the weight lifted before the muscle was fatigued?

(6) Through what average height was the weight lifted?

(7) Has the value of k or g changed?

(8) Give a formula for total height (H=).

(9) Give a formula for total work done (W=).

(10) Express in *ergs*, the total work done by the muscle.

(11) In the fatigue tracing did the lever continue throughout the observation to fall back to the original abscissa? If not, describe any general changes in the abscissa.

c. Reaction changes.

(12) Apply a piece of neutral litmus paper to the fresh muscle tissue of the frog from which your specimen was taken. Record result.

(13) Apply a piece of litmus paper to a fresh cut surface of the fatigued muscle. Record results.

(14) What is the reaction of the muscle of a frog after rigor mortis has been established?

(15) What is the reaction of fresh urine?

XV. Demonstration: Electrotonus; to determine the effect of a constant current upon the irritability of a nerve.

At the beginning of this century Ritter discovered that the vital properties of irritable and contractile tissues were modified when subjected to a constant battery current. This modified condition was called *galvanismus*. During the first half of this century the subject was investigated by Nobili, Mattencci, Valentin and Du Bois-Reymond; the last named substituted the word *electrotonus* for galvanismus and further modified the terminology. It remained for Pflüger (Untersuchungen über die Physiologie des Electrotonus, Berlin, 1859) to rework the whole field, to correct, to elaborate, and finally to formulate laws.

a. Preliminary experiment.

1. *Appliances.*—Muscle-signal; 2 Du Bois-Reymond keys; 2 Daniell cells; commutator; 8 wires; salt.
2. *Preparation.*—Set up electrical apparatus as shown in Pl. II. Fig. 8.
3. *Operation.*—Make and mount in the muscle-signal a gastrocnemius preparation.
4. *Observations.*
   (1) In which position must the bridge of the commutator stand to give a descending current? Mark that side of the commutator D. Mark the opposite side A.
   (2) With a descending current, which pole is the kathode, a or b?
   (3) Pl. II. Fig. 8-p represents the glass plate of the muscle signal. So arrange the triangular platinum electrodes that there shall be a distance of about 1 cm. between the electrodes, and both electrodes near

that end of the plate farthest from the muscle. Lay the nerve over the electrodes and along the glass plate. The segment of nerve which lies upon the glass plate between the electrodes and the muscle may be subjected to various stimuli, mechanical and chemical. Sterling (Prac. Phys., p. 244) uses salt. At a point about 1 cm. from the electrodes, marked x in the figure, place upon the nerve trunk as many fine crystals of common salt as would be taken up on the point of a penknife. Moisten these salt crystals with a drop of water. While the salt solution is permeating the sheath of the nerve trunk, adjust the commutator for a descending current. When the muscle begins to twitch, note the effect upon the signal. The contractions become more and more tetanic in character.

(4) Close the commutator circuit, open the short-circuiting key, i. e., *make* the "polarizing" current. If the experiment is successful the tetanus is more marked. Which pole is nearer the point stimulated?

(5) Close the short circuiting key, i. e., break the "polarizing" current. Reverse the commutator; make the current. The muscle is put completely or almost completely at rest. Which pole is nearer the stimulus?

(6) Repeat (4) and (5) several times. It is evident that the irritability of the nerve to the salt stimulus is increased in the region of the kathode, and decreased in the region of the anode pole. This changed condition of the nerve due to the passage of a constant current is called *electrotonus*. The state of increased irritability in the region of the kathode is called *katelectrotonus*. The decreased irritability in the region of the anode is called *anelectrotonus*.

b. Myographic record of anelectrotonus and of katelectrotonus.

1. Appliances.—3 or 4 Daniell cells; 3 Du Bois-Reymond keys; contact key; 2 commutators; inductorium; 2 N-P electrodes; 18 wires; kymograph; myograph with moist chamber; 2 pairs of platinum wire electrodes to use with induction currrent.

2. Preparation.—Arrange apparatus according to plan shown in Pl. II., Fig. 9. Note that the cross bars are absent from the commutator in the induction circuit. This enables one to stimulate the nerve at the central end (c) or at the segment between the polarizing electrodes and the muscle (m), by simply reversing the bridge of the commutator (B).

3. Operation.—Make and mount a gastrocnemius preparation in moist chamber myograph; adjust drum for tracing myogram. Adjust electrodes as shown in diagram.

Test apparatus and preparation by sending single make (or break) induction shocks through nerve at c or at m. Let there be a typical response at both places. The secondary coil should be removed to a distance that gives a little more than the minimum stimulus required to cause a contraction of the muscle.

To close the constant current "*polarizes*" the nerve or, better, *induces electrotonus*.

That segment of the nerve between the anode and kathode is called the *intra-polar region*.

Those segments centrally and distally located are called *extra-polar*.

The induced current is called the *stimulating current*.

4 Observations.

(1) Adjust for descending, polarizing current. Stimulate at c, i. e. in the region of anode. Note—trace—ex-

tent of muscle contraction. Induce electrotonus, stimulate again in region of anode. If the experiment is successful the contraction will be found to be decreased or absent.

The nerve is, at the point c, in a condition or *anelectrotonus* [descending extra polar anelectrotonus].

(2) Stimulate at m, or in the region of the kathode. Withdraw polarizing current. After a few minutes stimulate again at m. If the experiment is successful the wave is higher in the former than in the latter case.

The stimulation was made in the region of the kathode and the nerve in a condition of *kathelectrotonus.* [Descending extrapolar kathelectrotonus.]

(3) Adjust for ascending, polarizing current.

Stimulate at m, i. e., in the region of the anode. The contraction is weaker than in the normal nerve, or it may be quite absent. This region is now in a condition of anelectrotonus. [Ascending extrapolar anelectrotonus.]

(4) Stimulate in the region of the kathode. The response is probably weak. Withdraw the polarizing current. Stimulate again in the region of the kathode. The response is normal, i. e., it is greater than during the electrotonic condition.

But in *descending extrapolar* kathelectrotonus the response was greater than normal. In the experiment just performed we stimulated in the region of *ascending extrapolar kathelectrotonus.* Note that *the polarizing current is relatively strong.*

(5) Remove one cell from the battery and repeat (4.) If the response to stimulation is still weaker with than without the polarizing current, reduce the strength of the polarizing current still farther by use of the simple

rheocord. Finally with a *weak polarizing current*, the stimulus in the region of ascending extrapolar kathelectrotonus causes a *stronger* response than normal.

The response which the muscle makes must be accepted as a measure of the excitation which it receives from the nerve. But the excitation delivered by the nerve depends upon two factors, its *irritability* and its *conductivity*. When the nerve is stimulated in the region of ascending extra or intrapolar kathelectrotonus, its increased irritability is of no avail if there is interposed between that region and the muscle a region of decreased conductivity. With strong polarizing currents the region of the anode is not only decreased in irritability but *also in conductivity*.

Laws of electrotonus.

I. The passage of a constant current through a nerve induces a condition of electrotonus marked by an increased irritability in the region of the kathode (*kathelectrotonus*) *and a decreased irritability in the region of the anode* (*anelectrotonus*).

II. During electrotonus induced by a strong current the conductivity is decreased in the region of the anode. Further —though not derived from the foregoing experiment—"at the instant that the polarizing current is withdrawn the conducting power is suddenly restored in the region of the anode and greatly lessened or lost in the region of the kathode."—Lombard, in American text-book of Physiology.

XVI. Demonstration: Pflüger's law of contraction.

1. *Appliances.*—Du Bois-Reymond rheocord, or simple rheocord; 3 Daniel cells; muscle signal or myograph with moist chamber; 2 Du Bois-Reymond keys; commutator; 2 N. P. electrodes.
2. *Preparation.*—Set up the apparatus with three cells *in series*, Du B.-R. key as closing key. Commutator with cross-bars, Du B.-R. rheocord in short circuit, short-circuiting key, the two N P. electrodes clamped in chamber of myograph.
3. *Operation.*—Make and mount a gastrocnemius preparation.
4. *Observations.*

(1) Stimulate with make and break of the weakest possible descending current.

Record results in such a table as that suggested in laboratory lesson XII.

This table shows what response (contraction or rest) the muscle gives on the making and breaking of the descending current and on the making and breaking of the ascending current.

It also shows in a marginal column the gradual increase of the strength of the current through gradual increase of resistance in the short-circuiting rheocord.

(2) Make and break with weak ascending current. If the conditions are typical the muscle will contract on making both ascending and descending current.

(3) Increase gradually the strength of the electrode circuit, recording results. After a longer or shorter transitional period in which the result will be varied

by a contraction on both the make and break of the ascending current, one comes to a strength of current which causes a contraction on both make and break of both descending and ascending current. This is the medium strength for the preparation and the condition in question.

(4) Let the current be increased still further and by larger increments. After passing another transitional stage one finally reaches a strength of current which causes a contraction on make of descending current and break of ascending current. This is the strong current for the preparation under observation.

It not infrequently happens that through overstimulation and fatigue of muscle the whole experiment cannot be completed upon one preparation except by increasing the current by larger increments.

(5) Pflüger's law of contraction may be expressed in the following table:

STRENGTH OF CURRENT.	DESCENDING.		ASCENDING.	
	Make.	Break.	Make.	Break.
Weak.	C	R	C	R
Medium.	C	C	C	C
Strong.	C	R	R	C

(6) But how shall we account for these results?

Let us recall some of the laws which have been demonstrated.

Law I. The influence of make and break stimulation.

The make contraction starts at the kathode and the break contraction starts at the anode. Further, *kathodic or make contractions may be caused by a current which is too weak to cause anodic or break contractions.*

Law II. A law of Electrotonus.

The passage of a constant current through a nerve induces a condition of electrotonus, marked by an increased irritability in the region of the kathode, and a decreased irritability in the region of the anode.

Law III. A law of Electrotonus.

During electrotonus induced by a strong current the conductivity is decreased in the region of the anode.

With the help of these laws account for all the typical phenomena observed above.

PART II.

SPECIAL PHYSIOLOGY.

C. CIRCULATION.

XVII. The circulation and its ultimate cause. a. To observe the capillary circulation. b. To observe the action of the frog's heart.

a. To observe the capillary circulation.

1. *Appliances.*—Cork board 8 cm. wide by 20 cm. long and about ½ cm. thick; cover glasses, 18 mm. in diameter and 10 mm. in diameter; normal salt solution; camel's hair brush; pins; compound microscope; sealing wax; thread; filter paper; 2 per cent croton oil in olive oil.

2. *Preparation.*

Pith two frogs the day before the observation is to be made. At the beginning of the laboratory period when the observation is to be made curarize the frog lightly by the hypodermic injection of one drop of a 1 per cent solution of curare. Make a frog-board by cutting a hole 1.5 cm. in diameter near one corner of the cork board and fasten a large cover glass over the hole with sealing wax.

3. *Operation.*—After the frog becomes curarized, pin it out ventral surface downward in such a way as to bring one of the hind feet over the hole in the board. Tie thread, not too tightly, to the third and fourth digits, loop the threads over pins and gently separate the digits until the web is quite flat and closely approximated to the surface

of the fixed glass which covers the hole. Run a film of normal salt solution under the web; place a drop of the same liquid upon the upper surface of the web; place a small cover glass over it; fix the board upon the microscope stage so as to admit of illumination by transmitted light; illuminate; focus under low power.

4. *Observations.*

(1) Observe the movement of corpuscles within blood vessels of varying size and irregular course. Make a drawing of the field of observation showing the relative size, the course and anastomoses of the blood vessels.

(2) Observe whether the motion is equally rapid in all vessels; if not, observe whether the slower currents are in the larger or the smaller channels. Determine which of the vessels are arterioles, which capillaries, and which venules.

(3) Have you seen evidence of intermittent force acting upon the corpuscles? If so, describe its influence. Determine whether this intermittent force makes itself evident in all of the vessels; if not, in which class of vessels is it present?

(4) Do the corpuscles change shape? If so, under what circumstances?

(5) Remove the cover glass, dry the web with filter paper, touch a point with a pin that has been dipped into dilute croton oil. Without replacing the cover above the web observe whether the presence of the croton oil effects any change in the diameter of the vessels, or in the rate of the blood flow. If there is a change in both, has one a causative relation to the other?

(6) Note and describe minutely all changes which take place at and near the place touched with the croton

oil. If no marked change is produced by the croton oil, touch the point with a needle which has been dipped into strong nitric acid.

(7) Observe with a high power. Have you noted diapedesis of white or of red corpuscles. If so, describe the process minutely.

b. To observe the action of the frog's heart.

1. *Appliances.* — Dissecting board; fine scissors; heavy scissors; pins; forceps; watch glass; camel's hair brush; normal salt solution; fine silk thread; ice, in a beaker.
2. *Preparation.*—Pith a frog, lay it with its dorsal surface upon the dissecting board; stretch out its legs and pin the feet to the board.
3. *Operation* —Make a median incision through the skin from the pelvis to the mandible; make transverse incisions and pin out the flaps. Raise the tip of the episternum; insert a blade of the fine scissors under it and divide it transversely, about ½ cm. anterior to the tip. Raise the anterior segment of the sternum at the point of the transverse incision; insert the blade of the strong scissors under it and divide it longitudinally in the median line. Withdraw from the board the pins which fix the anterior extremities, make gentle, lateral traction upon the fore feet until the split sternum is sufficiently separated to afford a convenient working distance and to plainly expose the whole heart.
4. *Observations.*

(1) Note rate of systole.

(2) Note sequence of contraction of auricles, ventricle and bulbus.

(3) Note change in shape of different parts.

(4) Note change in color and the position of the same in the heart-cycle.

(5) Carefully excise the heart including the sinus venosus and the bases of the posterior and two anterior venæ cavæ, also the bases of the two aortic trunks. Place the excised heart in a watch glass. Observe whether the pulsation continues. If so, what is your conclusion regarding the relation of the heart movements to the central nervous system?

(6) If the pulsation continues, note whether the rate of pulsation has been noticeably changed by the excision.

(7) Bathe the heart with a few drops of normal solution. Hold the watch glass in the palm of the hand and note whether the rate changes.

(8) Float the watch glass upon ice water and note the results.

(9) If the heart seems vigorous (otherwise procure a fresh one), carefully sever the sinus venosus with the fine scissors. Does the sinus continue to beat? Does the heart continue to beat? Interpretation.

(10) If the heart beats, sever the auricle from the ventricle through the auriculo-ventricular groove. Note results.

(11) If the auricles beat, divide them. If they continue to beat, do they follow the same rhythm?

(12) If the ventricle becomes quiescent, stimulate it either mechanically or with a single induction shock. How does it respond to a single stimulus? Continue to subdivide the heart until the parts refuse to respond to stimuli.

(13) Repeat the experiment and see if the same results are reached on subsequent trials. Note results and give your interpretation.

XVIII. The graphic record of the frog's heart-beat.

1. *Appliances.*—Frog board; a straw or strip of bamboo 20 cm. long; a cork about 2 cm. in diameter and height; pins; needles; sealing wax; parchment paper; a kymograph, stand and lamp; a chronograph. (See Appendix A- 15.)
2. *Preparation.*—Use a pithed or a curarized frog. Make a heart lever after the model shown by the demonstrator.
3. *Operation.*—Open the abdomen of the frog as described under XVII-b-3 and expose the heart. Open the pericardium, place some resistant object—a cover slip for instance—under the ventricle. So adjust the heart lever that the cork foot of the long arm of the lever will rest upon the juncture of the auricles and ventricle. If the weight of the lever seems to be too great for the heart to move easily, the long arm may be made relatively lighter by placing a counterpoise upon the short arm. If the tracing point of the long arm has a sufficient excursion to make a good tracing, bring the kymograph to a position where the point will lightly touch the carboned surface of the drum. The lever should be nearly tangent to the surface of the drum, and so arranged that the rotating surface of the drum turns away from the tracing point of the lever rather than toward it.
4. *Observations.*
   (1) Note whether the curve is a simple one or composed of a major wave, with crests superimposed upon it.
   (2) In either case closely observe the phases of the heart-cycle and determine the relation of each part

of the cycle with each part of the tracing. If the tracing has a single crest, more delicately counterpoise the lever and more carefully adjust the narrow foot of the lever to the auriculo-ventricular groove and repeat the experiment.

(3) Take tracings of the auricle alone. Compare these with those of the auriculo-ventricular groove and determine the causes of the variation.

(4) Without altering the counterpoise take a tracing of the ventricle and compare it with the two preceding curves and account for all the differences.

(5) Try to take a double tracing with one lever foot resting upon the auricle and the foot of the second lever resting upon the ventricle. The tracing points must touch the drum in a vertical line. Are the crests synchronous? If not, why?

(6) If a time tracing be added by means of the chrono graph one may determine the time relations of the different phases of the heart cycle.

XIX. The apex-beat. The heart-sounds.

1. *Appliances.*—A cardiograph and a transmitting tambour (Marey) or materials for constructing them. A stethoscope; a stand and support; clamps; a kymograph; two tambour pans Nos. 1 and 2; thin sheets of rubber; thread; corks; sealing wax; tambour holder; straws; needles; parchment paper; chronograph.
2. *Preparation.*—With the materials furnished by the demonstrator construct a cardiograph and a recording tambour, [Appendix A., Nos. 8–9.]. Join the tube of the cardiograph to the tube of the recording tambour with a rather thick-walled rubber tube 50 centimeters in length. Fix the recording tambour with clamp and support, and bring it into adjustment for tracing the cardiogram upon the kymograph. Adjust chronograph.
3. *Operation.*—Let a student remove the clothing from the region of the apex beat of the heart and take, upon the table, a recumbent dorso-sinistral position. In some cases, however, better results are obtained if the subject sits beside the table. Place the button of the receiving tambour upon that point of the thorax most affected by the apex beat of the heart. The movements of the chest wall will be faithfully transmitted and magnified by the two tambours.
4. *Observations.*

(1) Note the exact point upon the chest where the apex-beat is most distinctly marked. Is it the same for different members of the class?

In recording the location of the apex-beat use the bony landmarks of the chest rather than the nipple.

In what intercostal space is it located? How far to the left of the median line of the sternum?

(2) Take several cardiograms from the same individual, being careful so to adjust the apparatus as to gain the maximum excursion of the lever. What features have all of these tracings in common? What features seem to be accidental and nonessential? What are the causes of the essential features? What are the sources of the nonessential features?

(3) Take cardiograms of several individuals. Do all of them possess the features which seemed essential in the first series, taken from one individual? If not, how would you account for the difference?

(4) With a stethoscope, whose construction you have carefully described in your notes, listen to the heart-sounds while the cardiograph is tracing the record of the heart-movements. Note that two sounds are audible and that there is a noticeable pause following the shorter, sharper sound; let us call the sound which succeeds the pause the first sound.

(5) With what part of the cardiogram does the first sound seem to correspond? With what part of the cardiogram does the second sound seem to correspond? Give reasons for this correspondence.

(6) As far as the data will admit, enumerate causes for the first sound; for the second sound; for the essential features of the cardiogram.

XX. The flow of liquids through tubes. Lateral pressure.

1. *Appliances.*—Reservoir with short discharge nozzle whose lumen is 6 mm. in diameter; 5 pieces of glass tubing whose lumen is about 6 mm. in diameter and whose length is 60 cm.; two lengths of glass tubing whose lumen is about 3 mm. in diameter and whose length is 60 cm; rubber tubing for joining up the apparatus; 3 T tubes of 6 mm. tubing; short tube with capillary point from each size of tubing; 2 one liter flasks; 2 supports; a light pine stick about 6 feet long; compressors (Mohr's).

2. *Preparation.*—A resourceful demonstrator will have no difficulty in contriving reservoirs. It is sometimes not easy to provide a large class with suitable and convenient reservoirs. The following form has proven very satisfactory: A glass tube about 3 cm. in diameter may be readily furnished with a glass nozzle of the required size by any glass blower. The nozzle should be about 3 cm. from one end of the tube. That end may be closed with plaster of Paris and filled with hard paraffin to the lower margin of the nozzle-opening. This reservoir may be held upright by a support. When complete it presents the appearance indicated in the accompanying figure.

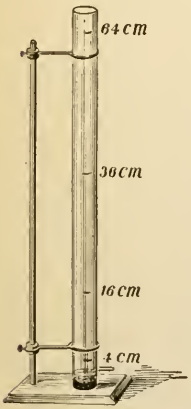


Fig. 15

3. *Operation.*—Mark upon the side of the reservoir a point 36 cm. above the center of the nozzle, also a point 64 cm. above the nozzle. While the reservoir is filled from one flask the water may be caught in the other. Assume some convenient unit of time, as 10 or 15 seconds.

4. *Observations.*—(*a*) Fill the reservoir to the height of 64 cm.

Allow the water to flow from the nozzle freely into the flasks. Observe the force with which the jet issues from the nozzle when the water begins to flow. Note the difference when the water in the reservoir reaches the 36 cm. mark; the 16 cm. mark. What are your conclusions?

(*b*) *Velocity.*—How does the velocity of the discharge vary with the varying height of the column of water? Why does it so vary? Does it verify the law of Torricelli? *The rate at which a fluid is discharged through an orifice* [better a nozzle] *in a reservoir is equal to the velocity which would be acquired by a body falling freely through a height equal to the distance between the orifice and the surface of the fluid.*

Recall the law of falling bodies. How far will a body fall *in vacuo*, the first, second and third seconds respectively? What is the constant acceleration per second, due to gravitation? What is the velocity at the end of the first, second and third seconds respectively? What is the total distance traversed at the end of the first, second and third seconds respectively? Let g equal the constant acceleration (approximately 32 ft. or 981 cm). Let h equal the total distance in centimeters, v the velocity and t the time in seconds. Derive from the facts the following equations:

(1) $v = g\,t.$

(2) $h = \frac{gt^2}{2}$

From these equations derive:

(3) $v=\sqrt{2gh}$; (approximately $=4\ 4.3\sqrt{h}$).

Expressed as a variation the constant may be discarded and the variable would read:

(4) $v \propto \sqrt{h}$, or $V : v :: \sqrt{H} : \sqrt{h}$.

Verify the truth of this mathematically derived law.

(*c*) *Discharge.* — The discharge of liquid flowing through an orifice must equal the product of the area of the orifice and the velocity with which the liquid flows. Let D equal the quantity of liquid discharged from the nozzle in a unit of time, and r equal the radius of the lumen of the discharging tube or orifice. Derive the formulæ:

(5) $D=4\ 4.3\pi r^2\sqrt{h}$.

(6) $D \propto r^2\sqrt{h}$.

Where one has to deal with two variables he may make one of them constant and verify for the other. When r is constant:

(7) $D \propto \sqrt{h}$, or $D : d :: \sqrt{H} : \sqrt{h}$.

When the height is constant:

(8) $D \propto r^2$, or $D : d :: R^2 : r^2$

Verify by experiment formula (7) as follows:

During a unit of time allow the water to flow from the 6 mm. nozzle, meantime maintaining a fixed level—e. g., at 64 cm.—by pouring water into the reservoir from a flask. Note the amount of discharge (D).

Make the observation also for the 36 cm. height. Verify formula (8) by determining D when the height is kept constant (64 cm.) and the radius of the discharge tube alone is varied. Use, for example, a 3 mm. nozzle. But there is another variable not considered above, namely, the resistance.

(*d*) *The relation of discharge to resistance.*—Attach to the nozzle one length of 6 mm. tubing. Note the

discharge in the unit of time. Attach a second length of the 6 mm. tubing, taking care that the tubing is approximately horizontal. Note the discharge in a unit of time. What is your conclusion? Why does the discharge decrease when the length is increased?

If R equals resistance and L length of tubing, does the following expression represent the facts:

(9) $R \propto L$?

Is the relation of discharge to resistance direct or reciprocal?

Verify the following formula:

(10) $D \propto \frac{1}{L}$

We have already found the formula $D \propto r^2\sqrt{h}$. Verify the formula:

(11) $D \propto \frac{r^2\sqrt{h}}{L}$

(*e*) *Pressure.*—Disjoin all tubes from the reservoir. Join a T-tube to the nozzle in this position ⊥; join a segment of large glass tubing to the perpendicular arm of the T-tube and support it in an upright position.

(1) Fill the reservoir to the 36 cm. mark, allow the water to escape from the distal end of the T-tube during a unit of time, meantime maintaining the height of the water in the reservoir. Carefully note the height at which the water stands in the upright tube—the *piezometer*.

(2) Repeat with water maintained at 64 cm. height in the reservoir.

(3) Join a length of large tubing to the distal end of the T-tube; repeat the experiment using only the 64 cm. height.

(4) Join a T-tube with piezometer No. 2, to the distal end of the segment of tubing just added

and repeat the experiment. (Note: The piezometers may be held in position by using the two supports and the pine stick.) Does the addition of the last T tube make any essential change in the height at which the water stands in piezometer No. 1? Does the reading of piezometer No. 2 agree with the reading of piezometer No. 1 in experiment (2).

(5) Add a second segment of large tubing. Repeat the experiment. Does reading of piezometer No. 2 correspond with reading of piezometer No. 1 in experiment (3)?

(6) Add piezometer No. 3. Repeat the experiment. Does reading of piezometer No. 3 correspond with that of No. 2 in experiment (4) and with No. 1 in experiment (2)? Does reading of piezometer No. 2 correspond with that of No. 1 in experiment (4).

(7) Attach a large capillary, repeat observations.

(8) Attach a fine capillary and repeat observations. What is the relation of pressure to height of column? Does pressure vary as height or as the square root of height?

(9) (*a*) What is the relation of pressure to the central resistance (Rc)? *i. e.*, the resistance between the point of observation and the reservoir.

(*b*) What is the relation of pressure to distal resistance (Rd)? *i. e.*, the resistance between the point of observation and the point of discharge.

(*c*) Which if either of the following formulæ represents the facts:

(11) $P \propto Rc$.

(11′) $P \propto Rd$.

XXI. a. The flow of liquids through tubes, under the influence of intermittent pressure. b. The impulse wave.

a. The influence of intermittent pressure.

1. *Appliances.*—Two glass tubes of about 6 mm. lumen and about 75 mm. long; a thin elastic tube—thin walled black rubber—of about the same lumen as the glass tube and about 150 cm. long; a double valved strong rubber bulb (about 7.5 cm. long); elastic tubing, large size; very thick walled rubber tubing for joining up the apparatus; Y tube; two flasks, or water receptacles; heavy linen thread; a wide capillary and a fine capillary or a piece of glass tubing 10 cm. long for constructing the same; 500 c. c. graduated cylinder.
2. *Preparation.*—Join the large elastic tube to the entrance valve of the bulb. Couple the two glass tubes closely and join one end to the exit valve of the bulb. Make all joints as close as possible and tie tightly with thread. Draw a coarse and a fine capillary tube from the 10 cm. piece of glass tubing.
3. *Operation.*—Clasp the bulb in the hand and make rhythmatical contractions at the rate of about fifteen in ten seconds. The process will, of course, pump the water from one flask into the other.
4. *Observations.*

a. Intermittent force and inelastic tubes.

(1) Does the stream of water which is ejected from the exit tube flow in a constant or in an intermittent jet?

(2) Attach a wide capillary and repeat. What is the character of the stream?

(3) Attach a fine capillary and repeat. Note the results.

b. Intermittent force and elastic tubes.

(4) Disjoin the glass tubing from the bulb and join the elastic tube. Work the bulb as directed above, and observe the character of the flow.

(5) Join on the coarse capillary and repeat, noting the change.

(6) Replace the coarse capillary with the fine capillary and repeat. Sum up the results and formulate conclusions.

c. Quantitative tests.

(7) How much water will be ejected through a fine capillary tube in ten seconds in experiment (3)?

(8) How much through a fine capillary in the same time in experiment (6).

NOTE: In performing experiments (7) and (8) great care should be used to exert exactly the same force upon the bulb. The same capillary should be used in the two experiments.

What is the significance of these two experiments?

b. The impulse wave. The graphic record.

1. *Appliances.*—Support; cork board (about 8 by 10 cm.); small glass rod about 20 cm. long; corks; needles; kymograph; piece of sheet lead 1 cm. wide and 5 cm. long; copper wire No. 16.

2. *Preparation.—Make a tracing lever* from the glass rod by drawing out one end to a rather fine point and drawing the other to about one-half its original diameter and bending it to make an angle of 135°. Bend up 1.5 cm. of each end of the sheet lead so that it will stand at right angles to the middle 2 centimeters;

bore the cork and pass the larger end of the tracing lever through it. Fix the cork board to a ring of the support with copper wire; fix the sheet lead to one end of upper surface of the cork board with copper wire and pass a needle through the limbs of the lead bearings and the lever-cork in such a way as to bring the lever over the middle of the board. The completed apparatus will have the relations indicated in the accompanying cut.

3. *Observations.*

(1) If the finger be held upon this elastic tube while the bulb is being rhythmatically squeezed, a series of impulses or pulsations will be felt by the finger

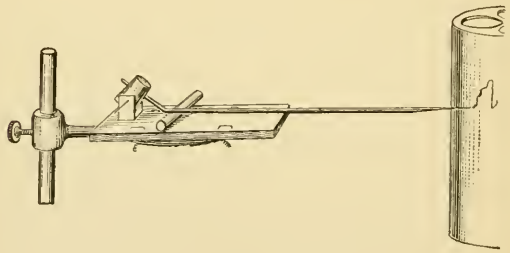


FIG. 16.

Place one finger upon the elastic tube near the bulb, and another three or four feet from the bulb. Let the bulb be pumped with sudden, but infrequent contractions. May one note a difference in the time of pulsation felt by the two fingers? If so, which is felt first? Why? What is the cause of the pulsation?

(2) To get a tracing of this pulse, pass the rubber tube across the cork board under the tracing lever [See Fig. 16]; adjust to kymograph and take tracing. Vary the character of the bulb contractions

as follows, taking one complete rotation of the drum for each variation:

(*a*) Slow initial contraction of bulb and slow relaxation

(*b*) Slow initial contraction of bulb and quick relaxation.

(*c*) Quick initial contraction of bulb and slow relaxation.

(*d*) Quick initial contraction of bulb and quick relaxation.

(*e*) Same as *d* with slow rhythm.

(*f*) Same as *d* with rapid rhythm.

(3) Make a careful study of these tracings and determine:

(*a*) The characteristic and essential features.

(*b*) The accidental and nonessential features.

(*c*) The cause of the essential?

(*d*) The cause of the nonessential features?

XXII. The laws of blood pressure determined from an artificial circulatory system.

1. *Appliances.*—Two large Y tubes of about 6 mm. lumen; four medium Y tubes, lumen about 4 mm; eight small Y tubes, lumen about 2 mm.; six thick walled capillary tubes, about 3 mm. outside measurement, and lumen not to exceed 1 mm. These capillary tubes should be about 15 cm. long. Two T-tubes of medium lumen; two

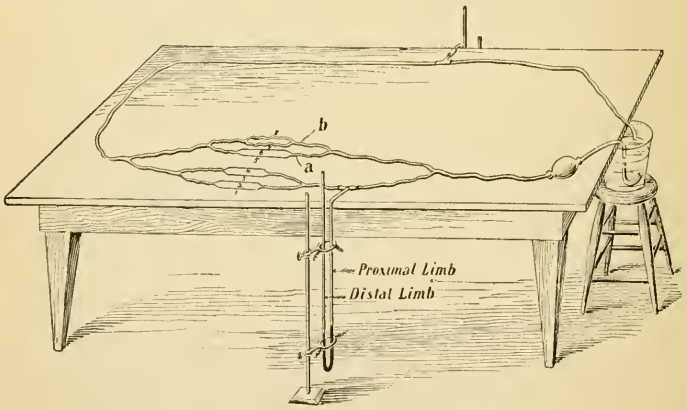


FIG. 17.

medium sized glass tubes about 75 cm. long. All rubber tubing should be thin walled and very elastic, and should be in three sizes, corresponding to the glass tubes. Two pieces of large size, 75 cm. long, and two pieces about half that length; four pieces of medium size, about 40 cm. long; ten pieces of small size; bulb; heavy linen thread; mercury; large glass receptacle for water, two medium sized rubber couplings.

2. *Preparation.*—First, make two manometers whose distal limb shall be 40 cm. long, and proximal limb 30 cm. with a horizontal shoulder 5 cm long. Second, draw out the two limbs of the medium Y tube until they are about the same in size as the small tubing (Fig. 18). Third, construct the artificial circulatory system according to Fig. 17.



Fig. 18.

3. *Operation.*—First, supply the manometers with mercury so that there will be 12 to 15 cm. in each limb of the arterial manometer, and 5 to 10 cm. in each limb of the venous manometer. If the class is not familiar with the use and interpretation of the manometer, the demonstrator should lead them to discover all of its essential features. Second, the whole system should be filled with water and freed from air before the observations begin. Third, care should be taken that no stoppage in the system occurs; otherwise the mercury may be thrown out of the manometers and lost.

4 *Observations.*

a. *The manometer* (mercurial).

(1) Find the actual pressure when the mercury in the distal column stands 6 cm. higher than that in the proximal column. Derive the following formula: Actual pressure $= 13.6\ \pi\ r^2(2\ m - \frac{m}{13.6})$, when r = radius of column of mercury, and m the rise of mercury in the distal limb of the manometer.

(2) Find the pressure per square cm. where the observation is the same. Derive the following formula: Pressure per unit area $= 26.2$ m.

(3) Which of these data (actual pressure or pressure per unit area) would be the more valuable to record?

(4) After the arterial circulatory system has been freed from air and is at rest, do the proximal and distal columns of mercury stand at the same level?

If not, why? What allowance, if any, should be made for this?

b. Arterial pressure.

(5) With capillaries 1 to 6 open and tubes 7 and 8 closed, let one member of the division make strong rhythmical contractions of the bulb at the rate of about 2 per second. Note effect on manometer. Account for all the phenomena.

c. Venous pressure.

(6) Note the effect of the contraction upon the venous manometer. If there is any change in the manometer, compare in rhythm and in extent with the changes in the arterial manometer.

d. Relations of arterial to venous pressure.

(7) Make very slow contractions. Note results.

(8) Make rapid, strong contractions. Note results.

(9) Make rapid, weak contractions. Note results.

(10) Remove the clamps from vessels 7 and 8 (local dilatation of arterioles) and repeat experiments 7, 8 and 9, noting and interpreting results. What effect does a dilatation of arterioles have upon venous pressure? What effect does it have upon arterial pressure?

e. Pressure formulæ.

Let: P =pressure.
Pa =arterial pressure.
Pv =venous pressure.
H =strength of contractions.
Rd=distal resistance beyond point of observation.
v =velocity at point of observation.
r =radius of vessel at point of observation.

How many of the following formulæ will your observations justify?

1. Pa $\propto$H.
2. Pv $\propto$H.
3. Pa $\propto$Rd.
4. Pv $\propto$Rd.
5. Pa $\propto$Pv.
6. Pa $\propto$H $\times$ Rd.
7. Pa $\propto r^2$.
8. Pa $\propto$H $\times$ Rd $\times r^2$.
9. Pa $\propto$v.
10. P $\propto$H $\times$ Rd $\times r^2 \times$ v.

f. Grafic record of pulse tracing from the artificial circulatory system.

With the recording apparatus used in Chapter XXI or with a sphygmograph, or better, with both pieces of apparatus, make tracings of the pulsations of the arterial tubes "a" and "b." (Fig. 17.) Compare all tracings carefully and interpret all the features of the record, differentiating the essential from the nonessential, as before.

XXIII. The pulse, sphygmographs and sphygmograms.

1. *Appliances.*—A sphygmograph; tracing slips; a fish-tail gas jet, or kerosene lamp.
2. *Preparation.*—Smoke about two dozen tracing slips.
3. *Operation.*—That the sphygmograph is so little used by the general practitioner may be attributed to the fact that hurry of business, or some other cause, has hindered him from making himself thoroughly conversant with the adjustment and use of the instrument, with its limitations and with the interpretation of the tracings.

To adjust the sphygmograph.

First. Let the observer stand with his right foot on a chair. This brings his thigh into a horizontal position.

Second. Let the subject stand at the right of the observer, resting the dorsal surface of the left forearm upon the observer's knee.

Third. Let the observer with pencil or pen mark the location of the radial artery.

Fourth. Let the observer wind the clockwork which drives the tracing paper; adjust the latter in readiness for tracing; rest the instrument upon the subject's arm with its foot upon the radial artery and adjust the position, tension and pressure, in such a manner as to obtain the maximum amplitude of swing of the tracing needle. Take the tracing. Fix.

4. *Observations.*

a. The location, etc., of the radial artery.

(1) What are the relations of the radial artery at the distal end of the radius?

(2) How may the relations vary?

(3) Is there any variation, among the members of the division, in the location of the radial artery?

(4) May excessive muscular development affect the ease with which the artery may be located and its pulsations studied?

(5) May excessive deposit of adipose tissue hinder the observations of the pulse?

(6) May faulty position of subject or of his clothing affect the pulse?

b. The digital observation of the radial pulse.

(7) Feel the pulse with the side or back of the finger; then with volar surface and tip of each finger of each hand and note the finger or fingers with which the feeling is most acute. It will be wise to always use these fingers in all tactile examinations. Their acuteness of feeling will increase with practice. One may thus acquire the educated touch—TACTUS ERUDITUS.

(8) How much may be learned of the pulse by means of the touch alone? Observe and note (*a*) frequency; (*b*) rhythm; (*c*) volume; (*d*) strength; (*e*) compressibility. (*f*) May anything else be determined by this method?

c. The Sphygmogram.

(9) Take at least three pulse tracings of each individual in the division. (*a*) Compare the tracings taken from one individual; if they differ, determine the cause of the difference. (*b*) Compare tracings of different members of the division. Determine, if possible, the causes of the differences.

(10) Do variations of the relations of the artery affect the sphygmogram? Does the adjustment of the instrument affect the sphygmogram? Does the

elasticity of the artery affect the tracing? How does strength or rate of heart-beat affect it?

Make a list of the facts regarding the condition of the circulatory system which may be determined with the help of the sphygmograph. Make a list of the precautions necessary to observe in the use of the sphygmograph.

XXIV. To determine the general influence of the vagus nerve upon the circulation.*

1. *Appliances.*—Operating case, (Appendix, A–3); a pair of curved, blunt-pointed shears, or better, a pair of barber's clippers; a rabbit board; large sheet of heavy paper; sealing wax; cotton; ether; thread; 1 Daniell cell; inductorium; vagus electrodes; 2 Du Bois keys; 7 wires; stethoscope; a strong, adult rabbit.

2. *Preparations.*—Let the six students be subdivided into three groups of two students each.

Let group "*a*" be responsible for the anæsthesia. Use the sheet of heavy paper to make a conical hood, whose spiral turns may be held in place with sealing wax. Place a wad of cotton loosely in the mouth of the cone.

Let group "*b*" perform the operation. Fix the rabbit, back downward, upon the holder; fix the nose in special holder (see Fig. 19); with the barber's clippers remove the hair from ventral side of thorax and neck; make hands and instruments *clean*, place instruments in a shallow basin of warm, 1 per cent carbolic acid solution; cut two or three ligatures of thread and place them in the instrument basin.

Let group "*c*" arrange the electrical apparatus for stimulation of the nerves. Fill the cell; join up with contact-key in the primary circuit, and a short-circuiting key in the secondary circuit. Test the apparatus to see if everything is in order.

3. *Operation.*

Group "*a.*" (1) Pour 2 cc. or 3 cc. of sulphuric

*Let six students work together.

ether upon the cotton in the cone; place the cone over the rabbit's nose; observe, and note carefully every step in the anæsthesia.

(2) Carefully note the rate of the heart before beginning anæsthesia.

(3) Keep the cotton moist with ether; watch the respiration and pulse, and be careful not to give the animal too much and interrupt the experiment.

Group "*b*." Wash the clipped surface of the throat.

After the rabbit is completely anæsthetized, make with scissors a median incision through the skin, beginning at the apex of the sternum and cutting anteriorly



Fig. 19.

for about 5 or 6 cm., divide the subcutaneous connective tissue over the middle of the trachea. Carefully separate from the median line on either side laterally the subcutaneous connective tissue with the associated adipose tissue.

How many pairs of muscles come into view? What two muscles approach the median line to form the apex of a triangle at the anterior end of the sternum? Observe a pair of thin muscles lying dorsal to the muscles just mentioned and joining in the median line to form a thin muscle sheet covering the trachea on its ventral side? What muscles are these?

Carefully lift up the median edge of the sterno mastoid muscle and separate with the handle of a scalpel

or a seeker the delicate intermuscular connective tissue. A blood vessel and several nerves come into view.

Is the blood vessel an artery or a vein? How many large nerves accompany the blood vessel?

Take hold of the sheath of the vessel, lift it up and note in the connective tissue accompanying the blood vessels two nerves, one large and one small. When the artery is in its normal position, what relation do these two nerves sustain to it? Which of the two nerves is external and which is dorsal to the blood vessel? Which is in close relation to the artery? What is the name of each of the nerves?

In preparing the nerve for stimulation one should neither grasp it with the forceps nor with the fingers. It may be separated from the delicate connective tissue in which it lies by use of a blunt seeker. Far better than any metallic instrument is a small glass rod drawn to a point, curved and rounded in the Bunsen lamp (see Fig. 11-A). Prevent the tissues drying up by occasionally pressing them lightly with pledgets of cotton moistened with normal salt solution.

Adjust the electrode carefully upon the vagus and see that no unnecessary tension is allowed to be exerted upon the nerve. It is usually necessary to hold the electrode in place during the observations.

4. *Observations.*

a. Anæsthesia. (Observations by Group "*a*.")

(1) Are you able to make out different stages in anæsthesia?

(2) How many stages did your animal manifest?

(3) Give the characteristics of each stage.

(4) What effect did the ether have upon the rate of heart beat?

(5) What effect did the ether have upon the respiration?

b. The stimulation of the vagus. (Observations by Group "*c.*")

(6) Stimulate moderately one vagus. Note with a stethoscope whether the rate of the heart is increased.

(7) Cut both vagi high up in the neck. Note the rate of heart beat at intervals of five minutes for twenty minutes, allowing the rabbit to partially recover from the anæsthesia.

(8) Stimulate one vagus. Compare the result with that obtained under experiment (6).

(9) Will very strong stimulation bring the heart to a standstill?

(10) If the heart was brought to a complete standstill by the stimulation, will it start up again spontaneously when the stimulus is removed? Will the rate reach the degree of acceleration observed in experiment (7)?

(11) Sum up the observations into a concise statement as to the influence of the vagus upon the heart.

NOTE: Dispatch the rabbit with chloroform.

D. RESPIRATION.

IX. a. External respiratory movements. b. Intra-thoracic pressure. c. Intra-abdominal pressure.

1. *Appliances.*—Operating case; clippers; rabbit board; rabbit; cone for anæsthesia; ether; kymograph; cardiograph, which may, in this case, be called a rabbit stethograph; three recording tambours; 10 cm. of glass tubing, 3 mm. lumen; rubber tubing to match; chronograph.
2. *Preparation.*
   (1) Fix and anæsthetize rabbit.
   (2) Clip ventral aspect of rabbit's thorax and abdomen.
   (3) Prepare thoracic and abdominal cannulæ by drawing the glass tube slightly in the center, cutting diagonally at the middle, smoothing diagonally on an emery stone.
   (4) Join a 30 cm. piece of rubber tubing to each cannula at the larger end, and clamp it near the cannula.
3. *Operation.*

a. External respiratory movements.

Place the button of the rabbit stethograph upon the ventral surface of the rabbit as near as possible over the junction of the diaphragm with the body wall, and a little to the right or left of the median line. So adjust the stethograph as to obtain the maximum excursion of the recording lever. The stethograph may be held in posi-

tion through the agency of a clamp and support; sometimes, however, better results may be secured by holding the stethograph in the hands, supporting the wrists on the edge of the rabbit board.

b. **Intra-thoracic pressure.**

Locate an intercostal space to the right of the sternum and opposite its middle point. Make an incision 0.5 cm. long, parallel with the intercostal space and 1 cm. from the sternum. Dissect through the intercostal muscles, taking care not to cut the pleura. Insert the point of the glass cannula into the wound, press it carefully through the pleura into the right pleural cavity.

Join the rubber tube to a recording tambour and unclamp. Slowly and gently manipulate the cannula until there is evident communication through the lumen of the cannula and tube from the pleural cavity to the tambour.

So adjust the cannula that the recording lever makes the maximum excursion. Bring the levers into such a relation to the kymograph that the tracing point of the stethograph lever shall be vertically over that of the lever which is to record intra-thoracic pressure, and about two centimeters from it.

c. **Intra-abdominal pressure.**

Make, in the median line of the abdomen, a one-centimenter incision, limited anteriorly by the xiphoid appendix. After partially dissecting through the abdominal wall insert the cannula into the incision and carefully press it through the peritoneum. If one push the cannula between the diaphragm and liver he will usually be successful in getting the free end of the cannula into an open space. Care should be taken not to wound the liver. Take tracing as in b.

4. *Observations.*

a. External respiratory movements.

(1) During one revolution of the drum—5 minutes—note the rate and rhythm of the respiratory movements as recorded by the stethograph, and chronograph.

(2) Does the stethogram show anything more than rate and rhythm?

(3) What phase of a respiratory cycle does a rise of the lever indicate?

(4) What is the relative duration of inspiration and expiration as indicated by the stethogram?

(5) Does the stethogram indicate any variation in different parts of the inspiratory act? Of the expiratory act?

(6) Differentiate the essential from the nonessential in the stethogram and determine as far as may be, the cause of each.

b. Intra-thoracic pressure.

Trace upon the drum a stethogram and chronogram as well as an intra-thoracic pressure record, taking care that the tracing points of the recording tambours are in a vertical line.

(7) Does the rhythm of varying pressure correspond to the rhythm of the respiratory movements?

(8) If so, does that necessarily establish between them the relation of cause and effect?

(9) What change of pressure is indicated by the rise of the pressure lever?

(10) What movement of the pressure lever corresponds to a rise of the stethograph lever?

(11) What is the condition of intra-thoracic pressure during inspiration? During expiration?

(12) Stop the entrance of air into the respiratory passages by closing the rabbit's nostrils. What effect does this have upon the respiratory movements?

(13) Is the intra-thoracic pressure affected by the experiment? If so, explain the effect.

(14) If two phenomena correspond perfectly in their cycles, and if a variation of one is always accompanied by a variation in the other, can there be any reasonable doubt that they sustain to each other the relation of cause and effect?

(15) Is one of the phenomena in question the cause of the other? If so, state which is the cause and establish your position.

To measure intra thoracic pressure.

(16) Clamp the rubber tube of the pressure apparatus. Replace the recording tambour with a water manometer. Unclamp.

Is the pressure during inspiration positive or negative, and how much?

(17) Is the pressure during expiration positive or negative, and how much?

(18) If the whole apparatus were filled with water instead of air and water, would it make any essential difference in the result? What effect do the variations of the intra-thoracic pressure have upon the circulation? Upon the respiration?

c. *Intra-abdominal pressure.*

Trace upon the drum a stethogram and chronogram as well as a record of the intra abdominal pressure.

(19) Does the rhythm of varying intra-abdominal pressure correspond with the rhythm of the respiratory movements?

(20) With what phases, respectively, of the respiration do rise and fall of the intra-abdominal pressure correspond?

(21) What influence upon the circulation would rise of the intra-abdominal pressure exert?

(22) Make a quadruple tracing: stethogram, chrono gram, intra-thoracic pressure and intra-abdominal pressure.

(23) Sum up the work of the day in a series of con clusions.

(24) Dispatch the rabbit with chloroform, noting the respiratory changes induced by the lethal dose of chloroform gas.

XXVI. Respiratory movements in man. a. The stethograph. b. The thoracometer. c. The belt-spirograph. d. The stethogoniometer.

1. *Instruments.*—Besides a kymograph and a chronograph, the following:

   Stethograph.—An instrument for recording graphically the movements of the chest-walls [Gould].

   Thoracometer.—An instrument for measuring (and recording) the movements of the chest-walls [Gould].

   Belt-spirograph.—An appliance for recording respiratory changes in thoracic or abdominal girth.

   Stethogoniometer.—An instrument for measuring the curvature of the chest [Gould].

2. *Appliances* needed in the adjustment and use of these instruments.—Heavy base support; three large clamp holders; iron rod, 8 or 10 mm. in diameter and 50 cm. long; two wooden or iron rods, 1 cm. in diameter and 40 c. m. long; a receiving tambour; a recording tambour. with support; two medium clamp holders; two universal clamp holders; simple myograph; 1½ meter fine fish cord; two pulleys.

3. *Preparation.*—For *construction* of apparatus see Appendix A, 10-13.

   Adjustment of the apparatus.

a. The Stethograph.

Clamp the center of the iron rod to the heavy base support. Clamp the wooden rods to the iron rods so that they will extend out to one side of the iron rod in a horizontal plane. Figure 20 shows the stethograph ready for use.

Let a member of the division remove all clothing above the waist and be the subject of observation for the other members. In making observations with the stethograph the subject should sit with his back or side to the table. The observer may readily adjust the stethograph to record the changes of any lateral or dorso-ventral diameter of the thorax. For all observations upon the respiratory changes in the thorax, the subject should keep the parts of the body symmetrically disposed.

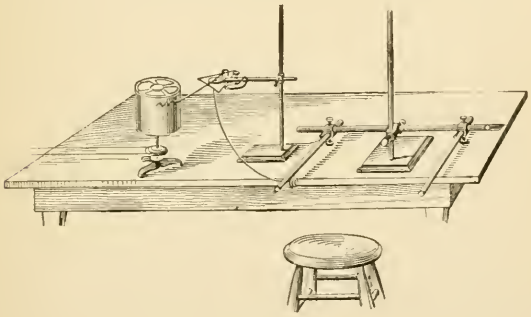


FIG. 20.

4. *Observations.*

(1) How much may be learned of man's respiratory movements by simple inspection? Make a careful enumeration and record.

(2) Adjust the stethograph and make a record—a stethogram—of the changes of the lateral diameter of the thorax at the ninth rib.

Does the stethograph show more than could be learned from inspection? If so, what?

(3) Take a stethogram of the lateral diameter at the sixth rib. How does it differ from the ninth rib stethogram? Account for the difference.

(4) Take a stethogram of the dorso ventral diameter of the thorax over the lower end of the gladiolus. Compare.

(5) Take a lateral ninth rib stethogram while the subject reads a paragraph; sighs; coughs; and laughs. Account for the peculiarities.

(6) Take a lateral ninth rib stethogram after the subject has taken vigorous exercise. What changes are to be noted?

(7) After a similar series of stethograms have been taken for others, compare; determine the essential features; give causes of these.

(8) Seek the causes of the difference which exist between stethograms of different individuals. May they be accounted for by stature, condition, occupation or habit?

b. The thoracometer.—Remove from the stethograph the wooden rod which bears the receiving tambour, and slip the iron rod of the apparatus described in Appendix A-11 into the same place with the button inward. The accuracy of the apparatus is increased if the heavy support which bears the spiral spring, just fixed in position, bear also the recording lever. Use a simple myograph lever which may be clamped to the support. The cord which runs over the pulley beneath the spring must change direction at least twice after leaving the first pulley. One will need two more pulleys such as the one described in the appendix. They may be held in position by clamp holders. If one use a horizontal drum, however, the cord may pass from the first pulley direct to the lever. In either case one would need to pass an elastic band around the short arm of the myograph lever in such a way as to draw the lever in a direction opposite to that

given it by the spiral spring. In every case the elasticity of the elastic band must be less than that of the spiral spring, otherwise the rubber button would not follow the movements of the thoracic wall. So adjust the apparatus that every movement, however slight, of the button will be instantly responded to by the lever.

(4) *Observations.*

(9) Carefully measure the arms of the lever to determine how much the tracing point of the lever will move for every millimeter that the button moves.

(10) When the button is pressed outward in inspiration what direction does the lever move?

(11) Take tracings of the changes in the dorso ventral diameter at the level of the nipples. Determine by measuring the tracing how much the dorso ventral expansion is. What is the average expansion during normal, quiet breathing? What is the expansion during forced respiration?

(12) Make a similar series of observations on the lateral diameter in the plane of the nipples.

(13) Repeat observations on the lateral ninth rib diameter.

c. The belt-spirograph.—Substitute for the rod of the thoracometer which bears the button and spring, a plain wooden or iron rod. Place the belt-spirograph around the subject at any level of the body, whose varying girth is to be observed. The fish cord used in the previous experiment may be transferred to this instrument. Tie one end into the eye in pulley No. 1, pass it over the other pulleys and to the lever; the horizontal bars may be raised to the axillæ and will serve to steady the subject. The expansion in girth of thorax is so great that it may be found necessary to

change the relative lengths of the lever-arms to avoid too great an excursion of the writing point of the lever.

(4″) *Observations.*

(14) How many millimeters will the point of the lever rise or fall for every centimeter that the girth increases?

(15) What is the average expansion of the thorax during normal quiet breathing?

(16) During five minutes—75 or 80 respirations—are all of the respirations practically the same or are there occasionally deeper breaths? If the latter is observed is there any regularity in the occurrence of deeper respirations? How may occasional deep respirations be accounted for?

(17) Let the subject make a series of forced respirations. What is the maximum expansion? What is the average expansion of the series?

d. The stethogoniometer.

This instrument is described in Appendix A 13. Its purpose is to record the outline of any horizontal section of the thorax, though it could be used as well for tracing the peripheria of the abdomen, of the head, or of a limb. To use the stethogoniometer for the purpose here intended let the subject sit beside a table upon a stool adjustable for height. So adjust the stool as to bring the circumference of the thorax to be observed even with the upper surface of the table. Fix the point c, of the instrument, to the table. Let the observer locate, with pen or pencil, upon the side of the subject distal from the table, a point which shall serve as a starting point.

When the point b, of the instrument, rests upon this point of the subject's thorax the instrument

should be well extended, somewhat more than represented in the figure. Fix a sheet of paper to the table under the recording pencil at a. *To take a graphic record of the contour of the thorax*, proceed as follows:

(18) (*a*) Let the observer place the tracing point b upon the "starting point" in the distal side of the thoracic perimeter.

(*b*) Sweep the tracing point quickly around one-half the perimeter to a point approximately opposite to the starting point.

(*c*) Rotate the curved arm of the instrument upon its axis bx, through 180°.

(*d*) Sweep the tracing point around the other one-half of the perimeter to the starting point.

(*e*) The movements of the tracing point, b, in the horizontal plane have been faithfully recorded upon the sheet of paper by the recording pencil at a. It is hardly necessary to remind the student that the subject must remain motionless during the observation.

(19) Take a thoracic perimeter with the chest in repose. Measure different diameters of the tracing and multiply by five to reduce to actual measurements.

(20) Take a tracing at end of forced expiration; at end of forced inspiration. Compare diameters.

(21) Make a series of these tracings for different individuals. Compare.

(22) Formulate conclusions.

XXVII. Respiration in man; lung capacity and strength of inspiration and expiration; chest measurements; the preservation of the data.

1. *Instruments.*—Spirometer; pneo-manometer; meter tape; steel calipers; standard, with horizontal arm for measuring height; scales for taking weight.

2. *Observations.*

(1) Test with the *spirometer* the lung capacity of each member of the division. May differences in lung capacity be accounted for by difference in stature, condition, occupation or habit?

(2) Take with the *tape* the *girth of chest* over the nipples in a plane at right angles with the axis of the thorax.

(*a*) With chest in normal repose.

(*b*) At the end of forced expiration.

(*c*) At the end of forced inspiration.

(3) Take the girth of chest over the juncture of the ninth rib with its cartilage, holding the tape in a plane at right angles with the axis of the thorax.

(*a*) With the chest in repose.

(*b*) At the end of forced expiration.

(*c*) At the end of forced inspiration.

(4) With the *calipers* measure the dorso-ventral diameter at the level of the nipple, holding the calipers in a plane perpendicular to the axis of the thorax.

(*a*) Normal, (*b*) after expiration, (*c*) after inspiration.

(5) Take the lateral diameter in the nipple-plane.

(*a*) Normal, (*b*) after expiration, (*c*) after inspiration.

(6) Take the lateral diameter at the ninth rib.

(*a*) Normal, (*b*) after expiration, (*c*) after inspiration.

(7) Test with the *pneo manometer* the force of inspiration and expiration. (Appendix, A 14). Let each member of the division test with the pneo-manometer the maximum positive pressure which he is able to produce in the respiratory passages during expiration.

(8) Test with the same instrument the maximum negative pressure which each individual can produce during inspiration.

(9) Does the face become red in either of these tests? If such is uniformly observed, account for it.

(10) The *preservation of data.* Experience has shown that when data are to be preserved for subsequent use in the comparison of one class of individuals or cases with another, it is very much more economical in time to record the data upon cards.

For the above data one may use such a card as is appended to this chapter.

In addition to the measurements above given record upon the cards the *weight*, the *height*, the bodily *condition* of the individual, and especially whether the individual has lived in a hilly or in a flat country, and whether he has been active or inactive.

Name .....
Age ..... Weight .....
Condition: Fat, medium or lean.
Muscular development .....
Previous occupation .....
Home ..... Flat or hilly region.
Habit: Inactive, active, (tennis, bicycle .....)
Lung capacity ..... Height .....
Girth of chest in repose .....
Girth of chest at end of forced inspiration .....
Girth of chest at end of forced expiration .....
Girth of chest at ninth rib, repose .....

Girth of chest after forced inspiration.....
Girth of chest after forced expiration.....
Diameter of chest dorso-ventral, in repose.....
full.....empty.....
Diameter of chest, lateral, in repose.....full.....
empty.....
Observer.....
Date.....

XXVIII. The evaluation of anthropometric data.

A large proportion of the problems that the medical man has to solve involves the finding of averages of a large number of observations. This is sure to be true of all anthropometric problems. In the course of the preceding lesson valuable anthropometric data were collected and recorded upon cards. The value of this material is purely potential. Before the data will furnish a basis for drawing conclusions it is necessary to subject it to a process of evaluation. This process consists, first, in grouping; second, in getting the average or the median value for each measurement; and, third, in graphically representing the averages. In the previous lesson the observer noted upon each card whether the subject had lived in a hilly or in a flat country; further, whether he had led a physically active or inactive life. This gives one an opportunity for four groups when the cards from the whole class are collected.

Group I. Active men from a hilly country.
" II. " " " flat "
" III. Inactive " " hilly "
" IV. " " " flat "

Until recently it has been customary to simply write the data for any group in columns and "strike an average" of each column. If there are only 10 to 20 or 30 individuals in each group this method does not entail the unnecessary expenditure of much energy, but it is not reliable; for one "giant" or "dwarf" in any group would vitiate

the whole result. If there are 100 or 1000 individuals in a group, then the use of the old method of finding the arithmetrical average is exceedingly wasteful of both time and energy. It must be added, however, that when the number of observations is large the chances are that there will be as many dwarfs as giants, thus making the average approximate closely the median value. It is the latter that we are seeking, viz.: the *median value;* this may be defined as that value which is so located in the whole series of observations, in a single measurement of any group, that there are as many below it as above it, i. e., that the numbers of values which it exceeds is equal to the number of values which exceed it.

Let us take a concrete case. In a group of 316 seventeen-year-old boys certain physical measurements were recorded upon individual cards. Let us take for an example the girth of head recorded in centimeters and tenths. Instead of writing in a column the 316 head girths, each expressed in three figures, adding and averaging, let us adopt the new method first suggested by the Belgian astronomer and anthropologist, Quitelet, and later elaborated by Galton, the London anthropologist.* Arrange the cards in piles, placing in one pile all of the cards having girth of head 51+ centimeters, in another pile all having 52+ centimeters, and so on. In the case in question it was found that the 316 cards were quickly distributed, falling into the following groups:

GIRTH OF HEAD.	51+	52+	53+	54+	55+	56+	57+	58+	59+	60+
NO. OF OBSERVATIONS (No. of Cards.)	1	7	17	41	70	74	60	29	10	7

* For a more extended explanation and development of this method than given in this chapter see also "Changes in the Proportions of the Human Body"—Hall. *Journal of the Anthropological Institute of Great Britain and Ireland.* London, August, 1895.

The problem is to find the value of the median measurement or the *median value.* There are 158 values below the median and as many above.

First. *To locate the median observation:* This is equivalent to saying—find in the lower series of numbers (1-7 17, etc.) the 158th observation from either end. It must be located in the pile of cards which numbers 74. This group may be called the *median group.* But where in this group is the median observation located? In order to determine this, add the groups at the left of the median group, these may be called the minus groups, the values which they represent being less than that of the median group. $1+7+17+41+70=136$. To this sum one must add 22 observations from the median group to make 158. The median observation is then located in the median group, 22 points from the left.

Second. *To evaluate the median observation* we must take it for granted that the 74 observations of the median group are evenly distributed over the distance between 56 cm. and 57 cm. That being the case the *median value* would be $56\frac{2}{74}$ cm.

Let us put a general proposition in the form of an algebraic formula.

Let M = the number of observations in the median group.

Let n = the total number of observations.

Σp = the sum of the plus groups.

Σm = the sum of the minus groups.

a = the minimum value of the median group.

d = the arithmetric difference in the minimum values of the groups.

μ = the median value to be determined.

Then $\mu = a + \frac{d(\frac{n}{2}-\Sigma m)}{M}$ or $\mu = a + d - \frac{d(\frac{n}{2}-\Sigma p)}{M}$

Apply this formula to the case taken for example:

$$\mu = 56 + \frac{1\left(\frac{316}{2} - 136\right)}{74} = 56.3.$$

or

$$\mu = 57 - \frac{1\left(\frac{316}{2} - 106\right)}{74} = 57 - 0.703 = 56.3.$$

After one has found the median value for each measurement in each group, these may be tabulated and the values compared. When the table of median values is large it is almost necessary to carry the work of reduction a step farther and represent these values graphically in a chart. Another opportunity will be used for giving the methods used in the graphic representation of statistical tables.

The table which results from the data collected in connection with the previous lesson is not so large but that the observer can practically comprehend the whole at a glance.

Our grouping enables us to answer the following questions:

First. Has general physical activity any essential influence in the development of the respiratory organs and function?

Second. Is the climbing of hills during early life a factor in the development of the respiratory organs and function?

If both of these questions may be answered affirmatively then one would expect to find that the median values of group I, (active individuals from a hilly country) uniformly exceed the values of group II; and that those of group III uniformly exceed those of group IV, but that the median values of group II may or may not exceed those of group III.

The following conclusions are quoted from a student's note book:

(1) "Every measurement of the 'median' active man is greater than the corresponding measurement of the 'median' inactive man."

(2) "Every measurement of the median active man from a hilly country is greater than the corresponding measurement of the median active man from a flat country."

(3) "But the active flat country men exceed in their median measurements the inactive hill country men, therefore, physical activity is a stronger factor in the development of respiratory organs than is the topography of the habitat."

XXIX. The action of the diaphragm.

1. *Appliances.*—Operating case; clippers; rabbit board, or dog board; rabbit or dog; ether; ether cone; absorbent cotton; kymograph; chronograph; recording tambour; beaker with warm water; medicine dropper or bulb. (If a dog be used, the medicine dropper will not be large enough, its place may be taken by a soft spherical rubber bulb about 2 cm. in diameter.) Inductorium, 1 cell, 2 keys, vagus electrode, 5 common wires and 2 fine wires. Sometimes the bulbs mentioned above, and usually used for this purpose, are not satisfactory. Very good results may be gotten by using a piece of glass rod, which has been rounded at one end and sharpened at the other, as a lever. (Fig. 21.) The rounded end is passed through the abdominal wall and rests against the diaphragm, (*d*). The point is inserted into the cork button of a tambour. Any contraction of the diaphragm presses the round end down, the body wall serves as a fulcrum (*f*), the point is pressed up and the lever of the recording tambour rises.
2. *Preparation.*—Fix the animal to the board; anæsthetize; clip anterior median region of abdomen. Put the bulb into the warm water, join the glass tube of the bulb to the recording tambour through a rubber tube. This apparatus thus joined may be called a *phrenograph* and its record a *phrenogram.*

   Set up electrical apparatus with short-circuiting key in secondary coil.
3. *Operation.*—From the posterior extremity of the xyphoid appendix make a median incision through the

abdominal walls. If the lever be used the incision should be just large enough to admit the lever, and should be located in the angle between the xyphoid and the costal cartilages on the right side.

Clamp with the serre-fines any small vessels which may be oozing. After having clamped the rubber tube, which connects the bulb to the tambour, carefully insert the warm, wet bulb between the diaphragm and the liver. The liver will usually afford sufficient resistance to cause alternate compression and relaxation of the bulb and a consequent rise and fall of the recording lever; if such be not the case, the liver may be held in place by two

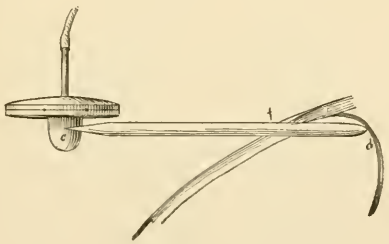


FIG. 21.

FIG. 21. Glass lever for transmitting movements of the diaphragm (*d*) to the receiving tambour. The abdominal wall forms the fulcrum (*f*) of the lever.

fingers inserted through the incision. In the meantime let another member of the division dissect out the left phrenic nerve. Fig. 22 shows the relation of the phrenic at the base of the neck, in the rabbit.

4. Observations.

a. Tactile observation of the diaphragm.

(1) In what condition is the diaphragm during inspiration? Expiration?

(2) In what position is the diaphragm during these two phases of respiration?

(3) What parts of the diaphragm make the greatest change of position during inspiration?

(4) What causes the diaphragm to arch anteriorly during normal expiration? Are the conditions changed during the present observations?

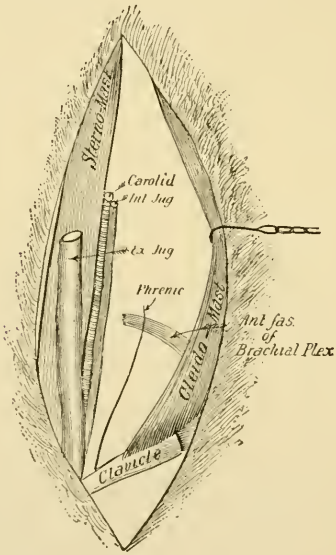


FIG. 22.

(5) Are the diaphragmatic movements synchronous with the costal movements?

b. The normal phrenogram.

(6) Take a phrenogram. What may be learned from it?

(7) Without varying the adjustment of the phrenograph bulb, take a tracing while repeatedly inter-

rupting the respiration by holding the nostrils What does the phrenogram show? What is the interpretation?

What effect upon intra thoracic pressure would the holding of the nostrils have?

c. The phrenic nerve and its function.

(8) Describe minutely the relations of the nervus phrenicus in the neck.

(9) Cut the nerve while tracing a phrenogram from the left side of the diaphragm. Note the result.

(10) Take a phrenogram from the right side of the diaphragm. Does it differ essentially from the normal?

(11) While taking a left phrenogram stimulate the distal end of the left phrenic nerve. Interpret the result.

(12) While taking a right phrenogram stimulate the distal end of the left phrenic nerve. Interpret the result.

(13) Dissect out and cut the right phrenic nerve. Does the diaphragm cease to move? If it moves, is its movement active or passive? Account for the phenomena.

Kill the animal with chloroform.

XXX. Respiratory pressure.

1. *Appliances.*—Operating case; clippers; rabbit board; ether; ether cone; absorbent cotton; rabbit stethograph; kymograph; a small mercury manometer, to the proximal limb of which is attached a thick walled rubber tube, a piece of glass tubing for a mouthpiece; a screw clamp; chronograph; two recording tambours; rabbit.
2. *Preparation.*—Fix and anæsthetize the rabbit, and clip the ventral surface of the neck. Join up the manometer as shown in Fig. 23.
3. *Operation.*— Make a longitudinal incision over the trachea. Carefully pass a strong linen ligature under the trachea. Make a median ventral slit in the trachea anterior to the ligature. Pass through the slit the limb of the Y-tube marked l. (Fig. 23.) Ligate.
4. *Observations.*
   a. *Respiratory pressure. The pneumatogram.*
      (1) After the ligature is tied how does the rabbit breathe? Are the thoracic and abdominal movements of respiration accompanied by other respiratory movements?
      (2) With tube n (Fig. 23) open is there any variation of the mercury during respiration?
      (3) With a screw clamp slowly close tube n. As the resistance to the flow of air increases what change is noted in the manometer?
      (4) Quickly clamp tube n at end of expiration and carefully note the manometer reading. Is it positive or negative?

(5) Clamp tube n at the end of inspiration. Is the pressure positive or negative?

(6) You have been determining certain facts regarding RESPIRATORY PRESSURE. Are the causes of the changes of respiratory pressure the same as the causes of the changes of intra-thoracic pressure?

(7) In what way does respiratory pressure differ from intra-thoracic pressure?

(8) Disjoin the manometer and join its tube to a recording tambour and trace a *pneumatogram*, with stethogram and chronogram.

(9) Compare the pneumatogram with the tracing of intra-thoracic pressure. Account for all differences.

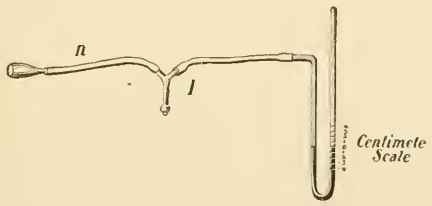


FIG. 23.

(*b*) *Stimulation of the pulmonary vagus.*

(10) Count the pulse. Adjust the stethograph, replace the manometer, and during the tracing of a stethogram place the mouth over the glass mouthpiece; quickly blow into the tube (n) until the manometer indicates two centimeters of intra pulmonary pressure; clamp, count the pulse. After a few seconds release the clamp and let the rabbit breathe normally for a few minutes.

Repeat the experiment. Vary by producing in turn 3 cm., then 4 cm. and finally 6 cm. of intra-pulmonary pressure. Fix the stethogram and compare.

(11) Compare your results with those obtained from other rabbits. What are the essential features of the modified stethogram? Formulate conclusions.

(12) What effect has a sudden increase of intra-pulmonary pressure upon the rate of the heart's action.

(13) What nerve is distributed to both lungs and heart? Admitting that it is possible for the observed effects to be produced through the agency of the nerves just named, state how this action may be accomplished.

(14) Could the effects be produced in any other way than in that which you have given?

(15) Is the demonstration unassailable; if not, what experiments would lead to results conclusive for or against the theory?

(16) Is the minimum intra-pulmonary pressure, which typically modified the stethogram, greater or less than the respiratory pressure of forced expiration?

(17) What effect upon intra-thoracic pressure would the induction of high intra-pulmonary pressure have?

(18) What effect upon blood flow would high intra-pulmonary pressure accompanied by repeated acts of forced expiration have? What incident effect upon the rate of heart beat?

(19) Dispatch the rabbit with chloroform after first arranging the apparatus for a pneumatogram. While holding the mouthpiece over or in a chloroform bottle or sponge, take a characteristic pneumatogram of chloroform poisoning.

c. The elasticity of the rabbit's lungs.

(20) After the death of the rabbit open the thorax

freely, taking care not to wound the visceral pleura. The lungs will collapse. Why?

(21) Replace the manometer, gently blow into the mouthpiece until the lungs have been inflated to their normal size. Measure carefully the rise of mercury in the distal column.

What degree of positive respiratory pressure will the elasticity of the lungs alone cause.

(22) What is the significance of the elasticity of the lungs in respiration?

d. The cardio-pneumatogram.—Remove the tube n from the Y-tube, join it to a recording tambour.

(23) Let a member of the division sit in perfect repose, and while the drum of the kymograph rotates very slowly, hold the mouthpiece between the lips. Hold the nose and suspend all respiratory movements for a period. Let some member of the division count the pulse of the experimenter.

Trace the cardio-pneumatogram.

(24) Is there a relation between the rhythm of the pulse and the waves of the tracing? If so, account for this relation.

(25) Account for the essential features of the cardio-pneumatogram.

XXXI. Demonstration: Quantitative determination of the CO_2 and H_2O eliminated from an animal in a given time.

1. *Appliances.*—A four-ounce Woulff bottle with three necks, and with delivery tubes and stopper ground in the necks [Fig. 24 a], three five-inch calcium chloride tubes, with side tubes and perforated glass stoppers, opening and closing the flow of gas [Fig. 24, c, e, f];

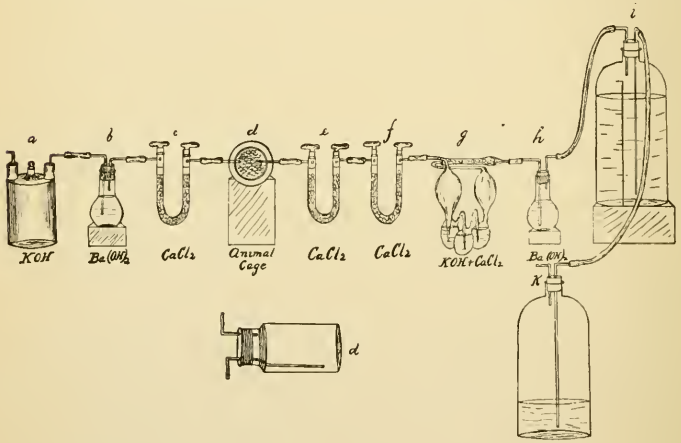


Fig 24.

Fig. 24. Apparatus for quantitative determination of the carbon dioxide gas and water eliminated from an animal in a given time.

Geissler's potash bulbs with $CaCl_2$ tube ground on (g); two small flasks (b, h) with rubber stoppers, double-bored, with delivery tubes fitted as shown in the figure; a one or two liter bottle with very wide mouth to use as an an-

imal cage, fitted with delivery tubes, and with a cork impregnated with paraffin; siphon apparatus, as figured, consisting of two 8 liter bottles with paraffined corks and tubes; analytical balances; laboratory balances (correct to 0.01 gm.); drying oven; chemicals, KOH, $Ba(OH)_2$, $CaCl_2$; any small animal whose weight in grammes does not exceed $\frac{1}{5}$ the volume of the animal cage expressed in cubic centimeters.

2. *Preparation.*

(1) Fill the calcium chloride tubes; put them into the drying oven, where they are to be kept at a temperature of 100° to 120° C. for several hours; cool in a desiccator and weigh upon the analytical balances the tubes e and f, recording the weight in milligrammes.

(2) Fill the Woulff bottle and the Geissler's bulbs with a strong solution (50% or more) of KOH. Fix into position upon the Geissler bulb, its filled and desiccated $CaCl_2$ attachment, and fit to each end a rubber juncture; clamp with strong serre-fine forceps and weigh upon the analytical balances.

(3) Fill the flasks b and h with a strong solution of $Ba(OH)_2$. These flasks serve simply to show whether or not the CO_2 gas has all been absorbed by the KOH through which it has just passed.

(4) Pieces e, f and g should be fixed to a light wooden rack, by which they may be moved; if this is not convenient clamp them to supports.

(5) Join up apparatus a, b and c.

(6) Fill siphon apparatus.

(7) Weigh the animal cage.

3. *Operation.*

(1) Put the animal into the jar; fix the cover so that it will not leak air.

(2) Join animal cage with c and with siphon appa-

ratus. Start the siphon and note the rate of flow per minute. The level of the water in the lower bottle should be probably 1 meter below that in the upper bottle. Notice whether the animal seems to be respiring normally; if so, it may be taken for granted, after ten minutes, that the ventilation is sufficient. If it seems insufficient one has only to increase the difference of level in the two siphon bottles.

(3) Disjoin the animal cage and weigh the cage with the contained animal upon the laboratory balances. Note the time; join the animal cage in circuit again, attaching it to e, and attaching z to h. Start the siphon. The greater resistance to be overcome will necessitate a greater difference in the level of the two bottles in order to ventilate at the same rate as before. To test joints put the finger over the distal tube of the Woulff bottle (a); if the joints are all right the siphon stream will stop after a few moments. When the water in the upper bottle is lowered nearly to the end of the siphon, clamp the tube joining h to i, set the empty bottle upon the floor and the full bottle upon the higher level, join the tube on at k and unclamp. This whole change need only occupy a few seconds. In the meantime CO_2 has been collecting, but it has not been lost.

(4) It is evident that in the afferent apparatus (a, b and c) one has a means of robbing the air of CO_2 and H_2O, thus furnishing the animal with pure, dry air. It is further evident that in the efferent apparatus one has a means of collecting absolutely all of the CO_2 and H_2O given off by the animal during the experiment. Further the weights before and after will show just how much of these excreta have been passed into the collecting apparatus.

(5) Note the time (one hour or more); clamp siphon tube; turn the stoppers of e and f, clamp x and y; disjoin d and weigh it.

(6) Weigh e; weigh f; weigh g.

4. Observations.

1) How much has the animal lost in weight during the period of observation?

(2) How much water left the animal cage during the period of observation?

(3) What was the source of this water?

(4) Did the animal micturate or defecate during the time of the experiment? If so, is this to be looked upon as a source of error in the experiment? Would such an occurrence tend to increase or to decrease the amount of water caught in the $CaCl_2$ tubes e and f? Would it cause a discrepancy between the loss in weight of the animal, as determined, and the combined weight of collected H_2O and CO_2?

(5) How much CO_2 left the animal cage during the observation?

(6) What is the total amount of H_2O and CO_2 collected?

(7) Does the amount of these excreta collected equal the loss in weight in the animal? What should the relation of these two quantities be? Explain in full.

(8) What is the *respiratory quotient?*

(9) Formulate several problems which may be solved with this method?

XXXII. Respiration under abnormal conditions.

1. *Appliances.*—Three small animals, e. g., mice, rats, guinea pigs or squirrels. Three wide-mouthed bottles or jars which may be sealed; scales or large balances; CO_2 generator; water bath; operating case; dissecting boards.

2. *Preparation.*—Determine the weight of each animal. Choose a receptacle whose cubic contents is about two to three times as many cubic centimenters as the weight of animal "a" in grams. Choose second and third receptacles whose contents represent about 12 to 15 c. c. to one gram of animals "b" and "c," respectively.

3. *Operation.*

I. Preliminary.

a. Put animal "a" into the small jar "a"; count respirations; close the jar.

b. Put animal "b" into jar "b." Before closing count respirations; close air-tight.

c. Fill jar "c" one-third full of water and displace the water with CO_2. Put animal "c" into the jar, taking care to allow as little loss of CO_2 as possible; close; count respirations.

II. Post-mortem examination.

After an animal dies fix it to the dissecting board and open the abdominal and thoracic cavities; take great care not to cut a large blood vessel; pin the flaps out so that all of the organs will be exposed and in place.

4. *Observations.*

a. Respiration in small closed space.

(1) Make careful record of number of respirations

and general condition of animal "a" in the normal state, and at the end of every five minutes after the closure of the jar.

What changes in rate or depth of respiration have been noted?

(2) Note all abnormal signs and symptoms.

(3) On post-mortem examination record the condition of heart, large blood vessels, lungs, liver, kidneys and the general appearance of the tissues.

(4) Compare the conditions with those found in a normal animal, prepared by the demonstrator.

b. Respiration in a larger closed space.

(5) Note all symptoms of animal "b" every five minutes after confinement in the jar.

(6) Make a post-mortem examination; record in detail the condition of the organs as in the case of animal "a."

(7) Compare animal "b" with the normal animal.

(8) Compare animal "b" with animal "a."

c. Respiration in an atmosphere of one-third CO_2

(9) Note all symptoms at intervals of five minutes.

(10) Compare these observations with corresponding ones from animal "a" and animal "b." What are your conclusions?

(11) Make a post-mortem examination; make a record as before.

(12) Compare appearances in animal "c" with those in the normal animal; with those of animal "a;" with those of animal "b."

(13) Make a generalized statement of the facts discovered in the experiments.

(14) What is the cause of death when an animal is inclosed in a small space?

(15) What is the cause of death when an animal is inclosed in a large space?

(16) Have the relations which you have discovered any bearing upon the future development of animal life upon the earth?

XXXIII. Respiration in abnormal media.

1. *Appliances.*—Three small animals; three jars or wide-mouthed bottles; hydrogen generator; nitrogen generator; water bath; potassium nitrite; ammonium chloride; operating case; dissecting boards.
2. *Preparation.*—Dissolve 66 grammes of ammonium chloride in 500 cubic centimeters of water. Dissolve 100 grammes of potassium nitrite in 500 cubic centimeters of water. Prepare a nitrogen generator as shown in the figure, using a liter flask. (Fig. 25.)
3. *Operation.*
   a. Pour the two solutions into the generator; adjust conducting tube; heat the mixture in the generator; in a few minutes nitrogen gas will be given off from the mixture as the result of the following reaction:

$$NH_4Cl + KNO_2 = 2H_2O + KCl + N_2.$$

   If the jars used by the different divisions are not too large the above suggested quantities of the solutions will probably supply enough gas for several divisions. Put an animal into the jar of nitrogen and close the jar.

   b. Fill a jar full of water, displace it with hydrogen gas. Put an animal into the jar and close it.

   c. Put an animal into a third jar, confining it with a cloth or a sheet of rubber. Join a rubber tube to an illuminating gas jet, introduce the end of the tube into the mouth of the jar; turn the gas on for an instant only. After five minutes allow another momentary puff of illuminating gas to enter the jar.

4. Observations.

a. Respiration in an atmosphere of nitrogen.

(1) Note all symptoms.

(2) How do these compare with those of death by oxygen starvation?

(3) Record post-mortem appearances.

(4) Compare with previous cases.

b. Respiration in an atmosphere of hydrogen.

(5) Note carefully every abnormal appearance and symptom.

(6) Make a record of the post-mortem appearances.

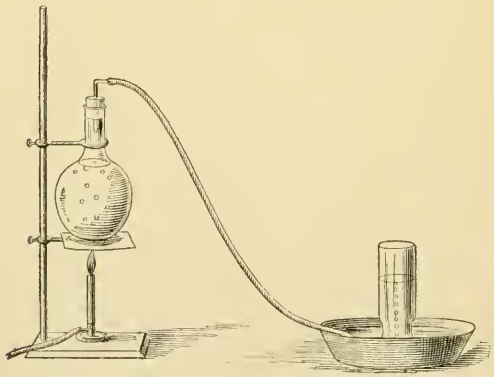


FIG. 25.

FIG. 25. Nitrogen generator.

(7) Compare these with the appearances after death by oxygen starvation; by CO_2 narcosis.

c. Respiration in an atmosphere of one-third illuminating gas (CO+).

(8) Record all symptoms.

(9) Record post-mortem appearances.

(10) How does death in an atmosphere of CO compare, as to symptoms, with death in an atmosphere of nitrogen?

(11) Compare it in turn with other forms of death as induced in this and the previous chapter.

(12) Compare the post-mortem appearances in this case with those in preceding cases.

E. DIGESTION AND ABSORPTION.

As intimated in the introduction it is taken for granted that by the time a medical school has found the conditions propitious for the establishment of a laboratory of experimental physiology, the whole province of chemical physiology will have been occupied by the department of chemistry as a legitimate growth of that department.

The American laboratory of experimental physiology will present, almost exclusively, the physical problems of physiology. But even where such are the conditions it may seem advisable to introduce into a course of lectures or recitations on the physiology of digestion a series of demonstrations.

The following exercises in the chemistry of digestion and the physics of absorption may be given either as demonstrations or as laboratory exercises.

This chapter is not intended as a substitute for any of the excellent treatises now used in medical schools, but rather as a supplement to them.

It will be taken for granted that the student has had at least one year of chemistry before he enters upon this course.

To give the course which is outlined one will need the following appliances, apparatus and reagents.

Appliances:

a. Glass ware utensils, &c.;

10 evaporating dishes, assorted sizes;
10 filters assorted sizes—5 cm. to 20 cm;
100 test tubes 15 cm;
10 beakers 30 c.c.;
10 beakers assorted—50 c.c. to 2 L.;
10 50 c.c. graduated cylinders;
4 graduated cylinders—100 c.c., 200 c.c., 500 c.c., 1000 c.c.
3 wedgewood mortars (2¾, 4 and 7 in. in diameter);
Filter paper;
Labels;
Pig bladders;
Thread;
Rubber tubing;
Glass stirring rods;

b. Apparatus.

3 Bunsen burners—with rubber tubing;
Filter stand;
2 supports with rings and gauze;
8 dialyzers
1 incubator;
Drying oven;
Meat hasher
Desiccator;
3 Water baths;
Platinum dish—15 c.c. to 100 c.c.

c. Reagents.

Diluted iodine;
Fehling's solution;
Sodium hydrate and potassium hydrate;
Copper sulphate;
Distilled water;

Neutral litmus ;
Concentrated nitric acid ;
Strong ammonia ;
Acetic acid;
Osmic acid 1 % ;
Pure standard pepsin ;
Muriatic acid C. P. (Sp. gr. 1.16=31.9 % abs. HCl ;)
Absolute alcohol ;
Ether ;
Chloroform ;
Calcium chloride ;
25 % solution NaOH ;
25 % solution KOH ;
½ saturated solution Na_2CO_3 ;
Nonmedicated absorbent cotton for rapid filtering of mucilaginous or albuminous liquids.

XXXIV. The carbohydrates.

1. *Materials.*—Potato starch; dextrin; dextrose; maltose; lactose; saccharose; cellulose represented by absorbent cotton and ashless filter paper.

2. *Preparation.*

(1) *To prepare Fehling's solution:*

a. Into a half-liter, glass-stoppered bottle put 34.64 gm. $CuSO_4$ c.p., and enough H_2O dist. to make 500 c. c. Label the solution: *Fehling's solution* (*a*).

b. Into a similar receptacle put 173 gms. of potassic-sodic tartrate — $KNaC_4H_4O_6+4H_2O$ [Rochelle salt] and 50 gm. of NaOH, weighed in sticks; add enough water to make 500 c c. Label: *Fehling's solution* (*b*). For use mix these two solutions in equal parts. A convenient quantity for the following experiments is 50 c. c. of each in 100 c. c. bottle.

(2) Prepare a starch paste by rubbing 1 gm. of starch to a creamy consistence with water, add 100 c. c. of distilled water and boil.

(3) Prepare a dilute solution of iodine by direct solution in water or by diluting an alcoholic solution.

3. *Experiments and Observations.*

(1) Put a little dry starch into an evaporating dish; add some dilute iodine. The starch turns blue. Pour a few drops of starch paste into a test tube; add a few drops of iodine. Iodine may be used to detect the presence of raw or of cooked starch.

(2) Put some raw starch into a test tube or beaker; add water; stir. The starch does not seem to be at all

soluble in water. Stir or shake the mixture to bring the starch into suspension in the water; pour upon a filter. A clear filtrate passes readily through. Test the filtrate for starch; result, negative; pour a few drops of iodine upon the filter, starch present. Conclusions:

(*a*) Potato starch is insoluble in cold water.

(*b*) The granules of potato starch will not pass through common filter paper.

(3) Dilute a few cubic centimeters of starch paste; pour it upon a filter; to the filtrate add iodine. The blue color indicates that in the cooking of starch the grains are broken up into particles sufficiently small to readily pass through the meshes of common filter paper.

(4) In order to determine whether dilute starch paste will in response to the laws of osmosis pass through an animal membrane, fill a dialyzer with dilute starch paste. Set aside to be tested one or two days later.

(5) Put a bit of absorbent cotton into a beaker or test tube; add water, boil; add iodine. Cellulose, as represented by cotton fibers, is insoluble in water and does not respond to the iodine test.

(6) Put a few bits of ash-free filter paper into a test tube; add water; boil; add iodine. Cellulose, as represented by the fibers of ash free filter paper, is insoluble in water and responds to the iodine test. One must remember in this connection that in the preparation of ash-free filter paper mineral acids are used to dissolve out the salts; and mineral acids, especially sulphuric acid, so modify cellulose that it responds to the iodine test with a blue color.

(7) Add water to dextrin in a beaker; stir with a rod. Dextrin is readily soluble in cold water. To a small portion add iodine. The solution will probably as-

sume a wine color; the typical reaction of erythro-dextrin.

(8) Fill a dialyzer with diluted dextrin solution and leave for subsequent examination.

(9) Add water to dextrose; it is readily soluble. Add iodine to a portion of the solution; result, negative.

(10) *Fehling's test for a reducing sugar:* To a few drops of the solution add several cubic centimeters of Fehling's solution and boil. A yellowish precipitate of cuprous oxide (CuO) appears. If the boiling is continued the color changes to a brick dust red.

(11) To a solution of maltose, add Fehling's solution and boil; the copper solution is reduced and CuO is precipitated.

(12) To a solution of lactose, add Fehling's solution and boil; reduction takes place.

(13) Subject a solution of saccharose to the Fehling test. No reduction occurs.

(14) *Tromer's test for a reducing sugar:* To any liquid suspected of containing a reducing sugar, add a few drops of very dilute $CuSO_4$ solution; to this mixture, add an excess of NaOH (or KOH); boil; if the suspected liquid contain a reducing sugar, the $CuSO_4$ will be reduced with precipitation of CuO. Subject all of the solutions of sugar in turn to the Tromer test. Note that the appearance is practically the same as with the Fehling test. Any differences are due, not to a difference in the essential reaction but to a difference in the proportions of the two reagents. The Fehling test is more satisfactory.

(15) Fill a dialyzer with a dilute solution of dextrose for subsequent examination.

(16) Fill a dialyzer with a dilute solution of maltose or lactose for subsequent examination.

(17) Fill a dialyzer with a dilute solution of saccharose for subsequent examination.

Questions and Problems.

(a) How may carbohydrates be classified? [Make three classes.]

(b) Which class has the lowest grade of hydration?

(c) How many of this class are soluble in cold water?

(d) How many are diffusible?

(e) Which class has the highest grade of hydration?

(f) Are all of those which belong to the third class soluble in water?

(g) Are they all diffusible?

(h) How may dextrin be classified?

(j) How many of the carbohydrates reduce $CuSO_4$ in presence of an excess of NaOH or KOH?

(k) How many of the carbohydrates are diffusible?

(l) How may one determine whether or not cane sugar passed through the animal membrane?

XXXV. Salivary digestion.

1. *Materials.*—Bread; fibrin; pig-fat; olive oil; starch paste; cane sugar.

2. *Preparation.*

Remove the parotid and submaxillary glands of several rabbits or rats, hash them; rinse quickly with water to remove blood; cover with water. After a few hours (12–24) filter or strain off the opalescent aqueous extract. It should contain an aqueous solution of ptyalin. Label: *Salivary Extract.*

(2) Chew a piece of rubber or paraffin. The flow of saliva is stimulated; catch the secretion in a beaker; dilute and filter. Label: *Salivary Secretion.*

(3) Fibrin for use in experiments on digestion may be procured in any quantity at a slaughter house. Rid it of all red coloring matter and of accidental contamination by repeatedly soaking and washing in water. The white, elastic shreds of fibrin may be kept indefinitely in pure glycerin. For use one needs only to wash out the glycerin thoroughly.

3. *Experiments and Observations.*

(1) Subject saliva (*a*) and (*b*) to the Fehling test. It will be found that neither the extract nor the secretion will reduce the $CuSO_4$.

(2) Subject starch paste to the same test. The result is negative.

(3) Mix equal volumes of starch paste and salivary extract in a beaker. Place the mixture in the incubator, which is kept at a temperature of 35° to 40° C.

After ten or fifteen minutes subject the mixture to a test with Fehling's solution. If the conditions are normal a copious precipitate of CuO indicates that a change has been wrought in the mixture. The starch has been changed to a reducing sugar by the ptyalin of the salivary extract.

(4) Mix equal volumes of starch paste and salivary secretion in a beaker, place the mixture in the incubator for ten or fifteen minutes; test with Fehling's solution. The presence of a reducing sugar shows that the secretion of the human salivary glands has the power to change starch to sugar; to change an insoluble, indiffusible foodstuff to a soluble, diffusible one.

(5) Put a few crumbs of bread into a test tube; add dilute iodine. Starch is an important constituent of bread.

(6) Put a few crumbs of bread into a beaker; add salivary extract; place in the incubator twenty minutes. Disintegration of the pieces and a marked increase of the amount of reducing sugar indicates the digestive action of saliva upon bread.

(7) Put a bit of fibrin into salivary extract; place in the incubator. An hour or a day will show no apparent change in the fibrin. Had one used any other proteid the result would have been the same. We are justified in the conclusion that saliva contains no ferment capable of changing proteids.

(8) Put a bit of fat or a drop of oil into a few cubic centimeters of salivary extract, shake vigorously; place in incubator. After an hour or day one sees no change in the fat or oil, and is justified in the conclusion that saliva contains no ferment which acts upon fats.

(9) To a small amount of *raw* starch add salivary ex-

tract, place the mixture in the incubator; shake frequently; after fifteen minutes test for reducing sugar. There will probably be a relatively small amount of reducing sugar. If one watches the progress of the digestion for several hours he will be convinced that the cooking of starch very greatly facilitates its digestion by saliva.

(10) Boil a few cubic centimeters of saliva; add starch paste; place in the incubator for ten minutes; test for reducing sugar. What is the verdict?

(11) Test the salivary secretion with neutral litmus. Determine whether its faint, alkaline reaction is essential to its action as a digestive fluid.

(*a*) To one portion of saliva add an equal volume of 0.3% hydrochloric acid and the same amount of starch paste. The mixture represents 0.1% hydrochloric acid. Place the mixture in the incubator for fifteen minutes; test with Fehling's solution. Verdict?

(*b*) Repeat the experiment substituting, for the hydrochloric acid, lactic acid of the same strength; place in the incubator for fifteen minutes; test with Fehling's solution.

What is the conclusion?

(12) *To determine the course of salivary digestion.* Mix 50 c. c. of salivary extract with an equal amount of starch paste. Test a portion with iodine at once. Test another portion at once with Fehling's solution. Keep the beaker in a water bath at blood temperature. Test a portion of the mixture every minute with iodine and another portion every minute with Fehling's solution.

(*a*) What is the first change noted in the digestion of the starch?

(*b*) How many steps may be made out with the means used and under the conditions existing in the experiment?

(*c*) In what order do the changes occur?

(13) Place some starch paste in a beaker which may be floated in ice water; similarly float a beaker with saliva. After both liquids have been cooled down to near the temperature of the surrounding water, mix them in one of the beakers; keep the mixture at the low temperature while subjecting portions of it every two minutes to the tests suggested above.

(*a*) May the same changes be made out in this experiment as in the previous one?

(*b*) Are the changes in the same order?

(*c*) State any differences in salivary digestion at blood temperature and at the low temperature (0°C) used in this experiment.

(14) (*a*) Sum up the day's work in a series of conclusions.

(*b*) What is the chemical formula of starch? Of erythro-dextrin? Of maltose? Of dextrose?

(*c*) Write a chemical reaction or a series of reactions which will be in harmony with the observations and show as nearly as possible the course of salivary digestion.

(*d*) What change has the ferment wrought in the starch molecule to render the resulting carbohydrate capable of diffusion through animal membrane?

XXXVI. The proteids.

1. *Materials.*—An egg; fibrin; gelatine; myosin; syntonin; acid albumin; commercial peptone (mixed albumoses, proteoses and peptones); Grübler's pure peptone.

2. *Preparation.*

(*a*) *To prepare myosin:*

(1) Take one pound of lean meat, grind it in the meat hasher; soak and wash repeatedly until the tissue is nearly white and quite free from hæmoglobin.

(2) Put the washed muscle tissue into a flask with an equal bulk of a 20% solution of ammonium chloride; shake from time to time for 24 hours.

(3) Strain off the liquor and add to it 20 volumes of distilled water. Myosin is precipitated. Wash the precipitate. Redissolve one-fourth of the precipitate in 10% NaCl, and label: *Saline Solution of Myosin.*

b. To prepare syntonin.—To the remaining three-fourths of the washed myosin add several volumes of 0.1% hydrochloric acid. In a very short time the myosin will be dissolved and changed to *syntonin.*

c. To prepare dilute egg albumin.—Make an opening in one end of the shell of an egg; drain off the white of the egg, catching it upon a coarse linen cloth—a towel serves the purpose well; press the albumin through the meshes of the linen into a beaker; add 400 or 500 cubic centimeters of distilled water; transfer the mixture to a 1 L. cylinder and shake vigorously; after a short time filter through pure absorbent cotton or strain through fine linen.

d. To prepare acid albumin.—To 100 c.c. of dilute egg albumin add an equal quantity of 0.2% hydrochloric acid; place the mixture in the incubator for two or three hours. Though the change begins at once it will probably not be complete before the time suggested. If one wishes to isolate the acid albumin from the mixture he has only to carefully neutralize with sodic hydroxide precipitating the acid albumin, and to wash the precipitate with distilled water. For the purposes for which it is to be used in the following demonstration it may be left in the acid solution which represents 0.1% HCl.

Label: *Acid Albumin Solution* in 0.1% HCl.

e.—Make an aqueous solution of the commercial "peptone," and though peptone is present in small proportion, label it: *Proteoses.*

f. Make an aqueous solution of a few grammes of Grübler's pure peptone, and label: *Peptone.*

g. Dissolve a few grammes of gelatin in distilled water.

h. To prepare Millon's reagent: 1st. To 100 grammes of pure mercury add an equal weight of concentrated nitric acid c. p. The reaction proceeds at room temperature, though gentle heat may be applied to complete the solution of the mercury. 2d. Cool the mixture; add two volumes of water; after 12 hours decant the supernatant liquid—*Millon's Reagent.*

3. *Experiments and Observations.*

(1) Pour into test tubes a few cubic centimeters of each of the following proteid solutions and subject each in turn to a temperature of 57°C, then to a temperature of 63°C, and finally a temperature of 100°C, by dipping the tubes into waterbaths of the temperatures named:

(*a*) Dilute egg albumin.

(*b*) Saline solution of myosin.
(*c*) Syntonin in acid solution.
(*d*) Acid albumin in acid solution.
(*e*) Gelatin in aqueous solution.
(*f*) Proteoses.
(*g*) Peptone.

Record the results in a table and formulate conclusions.

(2) Subject the same series of proteids to the *cold nitric acid test* by first pouring one or two cubic centimeters of strong nitric acid into a test tube, then with pipette carefully floating the proteid liquid upon it. In the case of dilute egg albumin a characteristic white ring forms between the acid and the albumin. Note in each case whether or not a typical ring is formed.

(*a*) Dilute egg albumin.
(*b*) Saline solution of myosin.
(*c*) Syntonin.
(*d*) Acid albumin.
(*e*) Gelatin.
(*f*) Proteoses.
(*g*) Peptone.

Tabulate results and formulate same in a concise statement.

(3) *The Xanthoproteic test.*

Use the tubes and materials already prepared in the cold nitric acid test. Shake the tubes to mix the acid with the proteid. In some cases a coagulum will be formed and this coagulum turns yellow on boiling if the tube is held in a Bunsen flame. After the coagulum has been boiled in the acid, cool under the hydrant or in a pail of ice water and add strong ammonia to alkaline reaction. The light yellow coagulum which forms in the case of egg albumin turns to an orange color.

This test is usually given as a universal proteid test. Tabulate results on the above suggested series (a)–(g) noting any variations of the reaction in the different proteids. Besides variations in the reaction with different proteids there are marked variations with different strengths of solution of the same proteid.

(4) A general test for proteids is to heat a proteid-containing liquid with half its volume of *Millon's reagent.* A precipitate appears which is yellowish at first but turns red under the influence of heat. Test each of the above list of proteids (a–g), with Millon's reagent. Record results.

(5) *The Biuret test.*

To a suspected liquid add an excess of sodic hydrate; shake well and to the mixture add one or two drops of a very dilute solution of cupric sulphate. A violet color appears which on heating becomes deeper in shade.

A most convenient reagent for this reaction is a mixture of the solutions (a) and (b) of the Fehling's test not in equal quantities as in the typical Fehling's solution, but in the proportion of nine parts of the sodic hydroxide solution (b) to one part of the cupric sulphate solution (a) and add an equal volume of distilled water to the mixture.

Tabulate results on the proteid series (a) to (g).

(6) Subject each of the series of proteids (a) to (g) to each of the following reagents tabulating results:

(I) Picric acid, saturated solution.
(II) Absolute alcohol.
(III) Mercuric chloride, saturated solution.
(IV) Tannic acid, saturated solution.
(V) Silver nitrate, 10% solution.
(VI) Ammonium sulphate, saturated solution.

On which of the proteid solutions would one get a precipitate with silver nitrate independent of the presence of proteid?

(7) *To separate peptone from other proteids.*—It will have been noted that ammonium sulphate precipitates all proteids except pure peptone. If one has peptone mixed with proteoses and unchanged proteids one may demonstrate its presence by precipitating out the other proteids and then demonstrating by such a test as the Biuret test the presence of a proteid in the clear filtrate; that could be nothing else than peptone.

Test commercial peptone in this way and determine whether any appreciable proportion of it is peptone.

(8) *The diffusibility of proteids.*—Fill seven dialyzers with the proteids above studied.

On the following day test the diffusates for proteids.

XXXVII. a. Diffusibility of proteids. b. Milk.

a. Diffusibility of proteids.

1. *Materials.*—The seven dialyzers filled at the end of the previous demonstration.
2. *Experiments and Observations.*

(1) What reagent may best be used to determine whether or not any of the egg albumin has diffused through the animal membrane?

(2) How may one determine whether or not any of the salts of the egg albumin have diffused through the membrane?

(3) In the case of the saline solution of myosin (b), of syntonin (c) and of acid albumin (d), is there any contraindication against silver nitrate as a reagent to determine whether proteid has diffused?

What would silver nitrate indicate in this case?

(4) What tests would be most reliable in these cases to detect the presence of proteid in the diffusate?

(5) Would a trace of proteid in the diffusate necessarily demonstrate the diffusibility of these proteids through the walls of the alimentary tract? If not; why not?

(6) What tests may be used to determine the presence of gelatin in the diffusate? Is gelatin diffusible?

(7) The term proteoses is a general one and is used to designate the mid-products of proteid digestion. The mid-product of albumin digestion is albumose; of globulin digestion, globulose; of myosin, myosinose; of vitellin, vitellinose; of casein, caseinose; or in general of a proteid, proteose.

Dialyzer (f) contains products of peptic digestion of proteids—principally albumin. The progress of digestion was suspended at a stage when there were present not only peptone but mid-products—albumoses; or, to use the general term, proteoses

The problem which confronts us is—*to determine whether or not proteoses are diffusible.*

(a) If peptone is diffusible the diffusate will certainly contain peptone. Do peptone and the proteoses respond alike to all the general tests for proteids?

(b.) How may peptone be separated from the proteoses?

What single reagent is indicated in the case?

(8) Demonstrate the diffusibility of peptone.

b. Milk.

1. *Materials.*—One liter of fresh whole milk; one liter of milk for the preparatory steps of the demonstration.

2. *Preparation.*

(1) On the day before the demonstration fill a 500 c. c. open mouthed cylinder with milk and put it in a cool place.

(2) Two days before the demonstration weigh out 10 gm. to 50 gm. of whole milk in a platinum dish or in a thin porcelain dish. Place it in a drying oven at 90°–95°C, and dry to constant weight. Record the dry weight.

(3) Before the hour of the demonstration burn the residue by bringing the dish which contains the dry solids to a red glow in a Bunsen flame, allowing ample access of oxygen. After the dish and the white ashes have cooled in a desiccator take the weight. All of these weights should, of course, be taken upon an analytical balance.

(4) Fill a dialyzer with diluted milk one day before the demonstration.

3. *Experiments and Observations.*

(1) What proportion of milk evaporates at the temperature above suggested? It may be taken for granted that this proportion represents practically the water of the milk.

(2) Of the solids of milk what proportion is organic and what proportion is inorganic?

(3) What bases predominate in the ashes? [Let a student be assigned this problem for solution.]

(4) What is the character of the organic constituents of milk?

(a) Note that the milk that has been standing has separated into two layers, an upper yellowish layer and a lower bluish white layer.

(b) Draw off with pipette a few cubic centimeters of the cream and in a test tube add an equal volume of osmic acid. To a few drops of olive oil in another tube add osmic acid. Shake both tubes vigorously. Osmic acid has the same effect upon the cream as upon the olive oil. The cream is, in fact, fat in physiological emulsion. Quantitative examination shows that about 4% of milk or 4-13 of the solids of milk consists of fats in which olein predominates.

(5) Fill a siphon with water and introduce it through the cream to the bottom of the 500 c. c. cylinder; draw off 300 c. c. of the milk; add to it four volumes of water; slowly add 1% acetic acid while stirring with a rod, until the casein separates as a copious flocculent precipitate. After the casein has partially settled decant off a few cubic centimeters of the supernatant liquid and subject it to the Fehling test. The abundant precipitate indicates the presence of a reducing

sugar. It is milk sugar — *lactose*. About 4.4% of milk or ⅓ of the solid matter of milk is *lactose*.

(6) Wash the casein by the repeated addition of water, followed by decantation; pour it into a linen sack or a towel and press out the water; further extract the water with absolute alcohol; extract the remnant of fat with ether; dry in the air. The white granular material that remains is nearly pure *casein*, the most important proteid of milk, and represents nearly 4% of milk.

(7) Heat 100 c. c. of the fresh milk in a beaker. Before the boiling point is reached a membrane gathers upon the surface of the milk. This membrane represents the *lact-albumin* of the milk, which has been coagulated by the heat and has collected in the membranous coagulum at the surface. The lact-albumin represents only a small proportion of the milk proteid.

(8) To 30 c. c. of fresh milk in a beaker add common salt to saturation. Record results.

(9) To 30 c.c. of fresh milk in a beaker add magnesium sulphate to saturation. Record results.

(10) Dilute fresh milk to one-fifth normal and subject it to the following tests, recording results:

(*a*) The iodine test.
(*b*) Tromer's test.
(*c*) The xanthoproteic test.
(*d*) The Biuret test.
(*e*) The picric acid test.
(*f*) The absolue alcohol test.
(*g*) The osmic acid test.

(11) Fill a dialyzer with the diluted milk. One day later examine the diffusate:

(*a*) For any of the inorganic constituents of milk.
(*b*) For the carbohydrate constituents of milk.

(*c*) For the proteid constituents of milk.

(*d*) For the fatty constituents of milk.

(12) Formulate in a series of concise statements the facts demonstrated regarding milk:

(*a*) Its chemical constituents.

(*b*) Its physical properties.

Why should milk be discussed in connection with the proteids rather than with the carbohydrates; considering that the proportion of carbohydrate in milk is greater than that of proteid?

XXXVIII. Gastric digestion.

1. *Materials.*—Two fresh pig-stomachs; ½ Ko. clean sea sand; 4 eggs; fibrin; bread; milk; jellied gelatin; casein; rennin.

2. *Preparation.*

(1) *To prepare artificial gastric juice.*

(*a*) Stretch a fresh stomach of a pig upon a board with mucous surface up; fix with nails.

(*b*) Rinse off the mucous membrane gently with cold water.

(*c*) Scrape thoroughly with a dull edged table knife, or an equivalent; collect the scrapings in a large mortar.

(*d*) Grind the scrapings in clean, fine sand.

(*e*) Add an equal volume of 0.2% HCl and leave for 24–48 hours, stirring occasionally.

(*f*) Strain through linen; filter, and preserve in a glass stoppered bottle. Label: *Acidulated aqueous extract of pepsin.*

(*g*) For use dilute this extract with three or four volumes of 0.1% HCl (App. A–17). Label: *Artificial gastric juice* (1).

(2) *To prepare a glycerin extract of pepsin.*

(*a*) Rinse off the mucous membrane of a fresh pig-stomach with cold water and remove the mucous membrane from the muscular walls of the stomach.

(*b*) Grind the mucous membrane in the meat hasher.

(*c*) Put the hashed tissue into a beaker and cover with two volumes of pure glycerin. Stir the mix-

ture occasionally for several days. The glycerin extracts the pepsin ferment.

(*d*) Strain the *glycerin extract* through fine linen; preserve in a glass stoppered bottle for future use. It will keep indefinitely.

(*e*) For use add to 1 volume of the extract 30 to 50 volumes of 0.2% HCl. Label: *Artif. gast. juice* (2).

3. *Experiments and Observations.*

(1) To a bit of starch paste of the consistency of jelly add artificial gastric juice (1); place in the incubator; in ten minutes or one day note results. Results?

(2) To a few drops of olive oil or to a bit of pure tallow add several cubic centimeters of gastric juice and keep at incubator temperature for a day. What effect has gastric digestion upon fat or oil?

(3) To a bit of pig fat add gastric juice and keep at incubator temperature for several hours. What effect has gastric digestion on adipose tissue?

(4) To a bit of fibrin in a test tube add gastric juice. The warmth of the hand will be sufficient. If the preparation of artificial gastric juice has been successful, the fibrin will dissolve in one or two minutes. One may be certain that digestion is progressing rapidly, though complete solution of the fibrin does not necessarily indicate complete digestion of it; for complete digestion of a proteid implies that the food stuff in question is both *dissolved and diffusible.* The fibrin is dissolved, it may or may not be diffusible. But this will be determined later.

(5) *To determine the active factors of gastric digestion.*

(*a*) To a few shreds of fibrin in a test tube add a few cubic centimeters of 0.2% HCl. Carefully note results. Will dilute HCl dissolve fibrin? Is it

possible to digest a proteid without dissolving it?

(*b*) To fibrin add dilute neutral glycerin extract of pepsin. Is solution affected?

(*c*) To tube (a) add a few drops of the glycerin extract of pepsin.

To tube (b) add 2 volumes of 0.2% HCl. Note results.

(*d*) Formulate conclusions.

(6) *To determine whether the acid factor of gastric digestion need necessarily be hydrochloric acid.*

Prepare a 0.4% solution of each of the following acids:

(I) Lactic acid.
(II) Sulphuric acid.
(III) Nitric acid.
(IV) Phosphoric acid.
(V) Citric acid.
(VI) Acetic acid.

For each acid prepare four test tubes as follows:

(I) *Lactic acid.*

(*a*) Fibrin + 1 c.c. glyc. ext. of pepsin + 10 c.c. 0.4% acid.

(*b*) Fibrin + 1 c. c. pepsin ext. + 10 c. c. 0.2% acid.

(*c*) Fibrin + 1 c. c. pepsin ext. + 10 c. c. 0.1% acid.

(*d*) Fibrin + 1 c. c. pepsin ext. + 10 c. c. 0.05% acid.

Proceed in a similar manner with each acid. Tabulate results. May any other acid or acids take the place of HCl as a factor in digestion? If so, in what minimum strength? Which one of the above acids may be normally present in the

stomach? May any of the above acids serve as digestives and as foods?

As digestives and as tonics?

As digestives, foods and tonics?

Cite authorities.

(7) *To determine the optimum strength of the hydrochloric acid.*

Prepare with care the following three dilutions of hydrochloric acid: 10%, 1%, 0.1%. [See Appendix A, 17.]

Into twelve test tubes put as many small masses of fibrin; into each tube put 1 c. c. of neutral 10% dilution of glycerin extract of pepsin. Label and fill tubes as follows:

Tube (a) 5%: Add to the fibrin 5 c. c. of 10% HCl and of distilled water a quantity sufficient to make 10 c. c.

Tube (b) 2%: Add 2 c. c. of 10% HCl and aqua dist. q. s. ad 10 c. c.

Tube (c) 1%: Add 1 c. c. of 10% HCl and aqua dist. q. s. ad 10 c. c.

Tube (d) 0.5%: Add 5 c. c. of 1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (e) 0.4%: Add 4 c. c. of 1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (f) 0.3%: Add 3 c. c. of 1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (g) 0.2%: Add 2 c. c. of 1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (h) 0.1%: Add 1 c. c. of 1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (j) 0.05%: Add 5 c. c. of 0.1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (k) 0.025%: Add 2.5 c. c. of 0.1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (l) 0.01%: Add 1 c. c. of 0.1% HCl and aq. dist. q. s. ad 10 c. c.

Tube (m) 0.005%: Add ½ c. c. of 0.1% HCl and aq. dist. q. s. ad 10 c. c.

Place these twelve tubes in the incubator and note conditions every 10 minutes for the first hour, every hour for the first six hours and then at the end of one or two days make the final observations.

Tabulate results. Formulate conclusions. What range of strength may, from the experiments with artificial gastric juice under artificial conditions, be considered the optimum strength for the acid? Is there any reason to doubt that the optimum strength as determined above is essentially different from the optimum strength in normal digestion?

(8) *To determine how dilute the pepsin may be and still be efficient in digestion.*

This experiment requires a standard solution of pepsin to use as a basis. The U. S. Pharmacopœia (p. 295 of the 7th Decennial Revision) gives the following formula for a standard solution of pepsin:

Hydrochloric acid (absolute), 0.21 gm.
Pepsin (pure), 0.00335 gm.
Water (distilled), q. s. ad 100 c. c.

The following suggestions are made as to method of preparation: To 294 c. c. of water add 6 c. c. of dilute hydrochloric acid:—Sol. A.*

In 100 c. c. of Sol. A. dissolve 0.067 gm. of standard pepsin:—Sol. B. To 95 c. c. of Sol. A at 40°C. add 5 c. c.

*HCl. DIL. contains 10% of Abs. HCl. The C. P. muriatic acid of standard Sp. Gr. contains 31.9% Abs. HCl.

Sol. B. The resulting mixture is a *standard artificial gastric juice* of the formula given above, and has the power of completely digesting at 38°–40°C one-fifth its weight of coagulated egg albumin in six hours.*

From a standard gastric juice prepare the following dilutions using 0.1% HCl as a diluent. It is scarcely necessary to say that the greatest care should be taken, (1) to make all measurements with precision; and (2) to thoroughly shake each dilution before drawing off the material for the next lower dilution.

(*a*) Standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*b*) $\frac{1}{10}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*c*) $\frac{1}{100}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*d*) $\frac{1}{1000}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*e*) $\frac{1}{10,000}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*f*) $\frac{1}{100,000}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

(*g*) $\frac{1}{1,000,000}$ standard artificial gastric juice 10 c. c. + 1 c. c. moist fibrin.

Keep tubes in incubator or water bath at 38°–40°C. Note (1) time required to dissolve fibrin completely, (2) time required to change all acid albumin to proteose or peptone. Will one-millionth standard gastric juice digest fibrin at all? Will a lower dilution (one ten-millionth) digest it; if so, how dilute, and how long a time is required?

*For details of testing standard gastric juice see Pharmacopœia.

XXXIX. Gastric digestion, continued.

3. Experiments and observations, continued.

(9) *To determine the influence of the hydrochloric acid of the gastric juice upon putrefaction in the stomach.*—It has been determined that the hydrochloric acid in the stomach destroys, under favorable conditions, at least the non-pathogenic forms of bacteria. Let us determine the strength of acid necessary to destroy the common bacteria of putrefaction. To each tube used in experiment (7) add a minute drop of any putrefying fluid. If the contents of a tube serve as a good culture field any drop of the fluid may be found to be swarming with bacteria within a few hours. Within a few hours after infecting the tubes examine under high power—700 to 1000 diameters—a drop of the contents of each tube. While making the observations take care not to contaminate one tube with the contents of another. That the tubes containing 5% or 2% or 1% hydrochloric acid will be found to be free from bacteria goes without saying. Just how weak may the acid be and destroy the bacteria? How weak may the acid be and retard their development? Could one readily drink enough liquid at a meal to change the stomach from a sterilizing field to a culture field for the bacteria of putrefaction?

(10) *To determine the influence of neutral salts upon digestion.*—Make a saturated aqueous solution of common salt; also $\frac{1}{4}$ sat. sol, and $\frac{1}{16}$ sat. sol.

(*a*) To 8 c.c. of NaCl sat. sol. add 1 c.c. of a 1%

HCl, and 1 c.c. glyc. ext. of pepsin; put the mixture into a test tube; label: *NaCl sub. saturated.* Drop in a bit of fibrin and put into the incubator. Take six test tubes, provide each with a bit of fibrin; label and fill each as follows:

(*b*) $\frac{1}{2}$ Sat. NaCl : — 5 c.c. artif. gast. juice + 5 c.c. NaCl sat.

(*c*) $\frac{1}{4}$ Sat. NaCl : — 6 c.c. artif. gast. juice + 2 c.c. NaCl sat.

(*d*) $\frac{1}{8}$ Sat. NaCl : — 5 c.c. artif. gast. juice + 5 c.c. NaCl $\frac{1}{4}$ sat.

(*e*) $\frac{1}{16}$ Sat. NaCl : — 6 c.c. artif. gast. juice + 2 c.c. NaCl $\frac{1}{4}$ sat.

(*f*) $\frac{1}{32}$ Sat. NaCl : — 5 c.c. artif. gast. juice + 5 c.c. NaCl $\frac{1}{16}$ sat.

(*g*) $\frac{1}{64}$ Sat. NaCl : — 6 c.c. artif. gast. juice + 2 c.c. NaCl $\frac{1}{16}$ sat.

What fraction of saturation with table salt stops proteid digestion? Explain its action. How much NaCl per litre would that represent? Has this any hygienic bearing?

(11) *The effect of mechanically confining the fibrin to prevent its swelling.*—Tie a small mass of fibrin rather tightly with several turns of white thread; drop it into a test tube containing artificial gastric juice; put the tube into the incubator and watch results.

How long a time is required to digest the fibrin? Has this any hygienic significance?

(12) *The influence of division upon the time required to digest proteids.*—Boil an egg five to ten minutes; cool quickly; separate the hard coagulated white from yolk and envelopes.

(*a*) Cut out a one centimeter cube and put it into a beaker with 40 c c. artificial gastric juice.

(*b*) Put into a second beaker of 40 c.c. gastric juice a centimeter cube which has been divided into eight half-centimeter cubes.

(*c*) Prepare another beaker in which are 16 quarter centimeter cubes in 10 c.c. of artificial gastric juice.

(*d*) Into another beaker with 10 c. c. artificial gastric juice put $\frac{1}{4}$ of a cubic centimeter of the egg albumin which has been finely divided by pressing through a fine sieve.

Note time required in each case to completely digest the albumen.

Has this any hygienic bearing?

(13) *The influence of temperature upon the time required to digest proteids.*—Prepare five tubes by first providing each with 5 c.c. of artificial gastric juice; treat the several tubes as follows:

(*a*) Bring to 60°C. in water bath; add fibrin; note time.

(*b*) Bring to 50°C. in water bath; add fibrin; note time.

(*c*) Bring to 30°C. in incubator; add fibrin; note time.

(*d*) Leave at room temperature (20°C.); note time.

(*e*) Bring to 0°C. in ice water; add fibrin; note time.

What is the optimum temperature?

Is the progress of digestion materially retarded by a reduction of the temperature?

Would the temperature of the stomach contents be essentially lowered by the occasional sipping of an iced beverage during a meal?

What is the hygienic significance of the experiment?

XL. Gastric digestion, continued.

3. Experiments and Observations, continued.

(14) *The steps of gastric digestion.*

Boil an egg 5 to 10 min.; cool quickly; separate out the white; press it through a fine sieve; put into a beaker with 100 c. c. artif. gastric juice, and place the beaker in a water bath at 40°C. At intervals of 2 minutes for the first 10 minutes; then at intervals of 5 minutes for the next 20 minutes; then at intervals of 10 minutes for the second half hour and after that at intervals of one hour, subject the liquid to tests for egg albumin; for acid albumin; for albumose; for peptone. In what order and after what length of time do the several products appear? Is the one that is first to appear also first to disappear?

(15) *The artificial digestion of various proteids.*

(*a*) To a small mass of jellied gelatin add 10 to 15 volumes of artif. gast. juice, and note effect.

(*b*) Subject bread to the xanthoproteic test. The presence of proteid material is demonstrated. Put a small piece of dry bread into a beaker with gastric juice, and note effect.

(*c*) Note the course of casein digestion.

(*d*) Triturate in a mortar well cooked lean meat; digest with gastric juice.

(*e*) Try the xanthoproteic test upon cooked beans or peas; proteid is present. Triturate in a mortar; digest.

(*f*) In each case, demonstrate the ultimate appearance of peptone.

(16) *The artificial digestion of milk.*

Of fresh milk take three portions of 5 c. c. each.

(*a*) To one portion add 10 volumes of artif. gast. juice; and place it in the incubator at 38°—40°C.

(*b*) Prepare another beaker in the same way but place it in a water bath at 38°—40°C. and keep the mixture well stirred, dividing the casein coagulum as fine as possible.

(*c*) Place the third portion of milk in the water bath. When it has become warm add a few centigrams of *rennin*. Fifteen minutes later add artif. gast. juice. Stir as in (b.) In which of the first two does digestion seem to progress the more rapidly? Does the progress or process of the digestion seem to be materially different in the last two experiments, (b) and (c)? Have any of the observations made on milk digestion any hygienic significance?

(17) *The diffusibility of the products of the artificial digestion of proteids.*

From the products of digestion in experiments (16-b) digested milk, (15-a) digested gelatin, (15-b) digested bread, and (12 d) digested egg albumun, fill four dialyzers—first neutralizing the acid with sodic carbonate. After 12-24 hours, test the diffusate for peptone. Why neutralize the liquid before filling the dialyzer?

Have all of these indiffusible proteids been wholly or in part changed to diffusible peptones by the action of the artif. gast. juice?

XLI. The properties of fats.

1. *Materials.*—Olive oil; cream; butter; beef tallow; lard; adipose tissue; cotton seed oil.

2. *Experiments and Observations.*

(1) *The osmic acid test.*—Place in test tubes a small amount of each of the above food stuffs; add to each a few cubic centimeters of osmic acid. A characteristic reaction takes place, the result of which is a deep brown coloration of the fat. If the conditions are favorable the stain deepens into a sepia black. The cream and the adipose tissue have proteid admixtures; note the variation of the reaction.

(2) *The solubility of fats and oils.*—Prepare three tubes each of olive oil, of cream, and of tallow; treat each material with absolute alcohol, with ether and with chloroform. It will be found that all of these reagents are solvents of fats and oils. The alcohol, however, dissolves very much more of the oil or fat when warm than when cold, as may be demonstrated by making the alcoholic solution with the tube immersed in boiling water; after the alcohol seems to have reached the limit of solution at that temperature, immerse the tube in cold water. A large part of the dissolved oil instantly separates out, but will readily redissolve on again immersing the tube in the boiling water.

(3) *The saponification of fats and oils.*

(*a*) To about 2 c. c. of olive oil in a test tube add 1–2 volumes of a 25% solution of sodic hydrate. Shake the mixture vigorously; it is evident that a chemical reaction is in progress. The fat is undergoing the

process of *saponification*. A complete and typical saponification requires a more careful apportionment of the amount of oil and of alkali used and an application of heat.

(*b*) Repeat the experiment substituting a 25% solution of potassic hydrate. The result is similar.

(*c*) What is the chemical formula of palmitin? Of stearin? Of olein?

(*d*) What is the chemical formula of palmitic acid? Of stearic acid? Of oleic acid?

(*e*) Write generalized formulæ for each of these acids.

(3) Write the reaction which takes place in saponification of palmitin; of olein. Note the ready solubility of the products of this reaction in water.

(4) To a solution of soap add any aqueous solution of a calcium salt soluble in water, *e. g.*, calcium chloride—a curdy white precipitate separates out. Write the formula of the reaction.

May the reaction have any relation to hygiene or therapeutics?

(5) *The emulsification of oils.*—Gould defines an emulsion as "water or other liquid in which oil in minute subdivision of its particles is suspended." One may add, *more* or *less permanently* suspended. For, if one shake together vigorously 2 c. c. of oil with an equal amount of water in a test tube he is able to bring about a minute subdivision and *temporary* suspension of the oil in the water. While the oil is in this temporary physical condition it has the white color typical of emulsions in general. In a few minutes, however, the particles, as they rise to the top of the liquid coalesce into minute globules; then into larger and larger globules and finally into a homogeneous, supernatant oil-layer.

(*a*) Add to the mixture above described 2 or 3 c. c. of strained egg albumin; shake vigorously. One observes the same minute subdivision of the particles, but they show no tendency to coalesce on standing; the suspension is "*more or less permanent.*"

Why do not the particles coalesce? In what respects is this emulsion unlike milk?

(*b*) To 2 c. c. of olive oil add 2 c. c. of sirupy solution of any gum, *e. g.*, gum acacia; shake the mixture thoroughly. An emulsion will be formed. What characteristics has this emulsion in common with emulsion (a)?

(*c*) To 5 c. c. of cotton seed oil containing a little free fatty acid add 10 drops of strong sodium carbonate solution and shake. A good stable emulsion is made in this way. [Long's Chemical Physiology, p. 63.]

In what way is this emulsion different from those which precede? Which one of the emulsions given above is most like the emulsions formed in the small intestine?

(*d*) What matters present in the small intestine tend to promote emulsification of fats?

(6) *The diffusibility of fats or their derivatives or modifications.*

Fill five dialyzers as follows:

(*a*) Milk.

(*b*) Solution of soap.

(*c*) 10% glycerine.

(*d*) Emulsion (5-a).

(*e*) Emulsion (5-c).

Complete the observations on the following day, determining what derivations or modifications of fat or oil are diffusible. How may the presence of soap in the diffusate be determined?

XLII. Intestinal digestion.

1. *Materials.*—2 pig pancreases; 200 c. c. of pig or ox bile.

2. *Preparation.*

(1) *Aqueous pancreatic extract* (a).

(*a*) Free a pig pancreas of fat.

(*b*) Grind it in a meat hasher.

(*c*) Extract with water kept at a temperature of 25° to 28° C.

(*d*) After two hours strain through linen and filter through absorbent cotton.

(2) *Glycerin extract of the pancreatic ferments.*

(*a*) After freeing the gland of fat, grind it.

(*b*) Place it in two volumes of absolute alcohol for two days.

(*c*) Drain off the alcohol and transfer to 2 volumes of pure glycerin.

(*d*) After one week press out the glycerin, which has extracted the ferments.

This glycerin extract will keep indefinitely. *To make artificial pancreatic juice* proceed as follows:

(*e*) To 1 volume of the glycerin extract add 5 or 6 volumes of water and sufficient sodium carbonate solution to give the mixture a distinctly alkaline reaction.

(3.) *Preliminary experiments on bile.*—This secretion may be easily procured from the slaughter house at almost any time in the year, whereas the gastric juice and pancreatic juice may only be obtained by resort to

operative procedures not properly in the field of this chapter.*

(*a*) To diluted bile add dilute acetic acid. The copious yellow precipitate is mucin.

(*b*) To diluted bile add absolute alcohol; mucin is precipitated; filter. To one portion of filtrate add HCl. The yellow precipitate is glycocholic acid.

"To the other portion of the filtrate add lead acetate, which throws down lead glycocholate. Remove this by filtration, and to the filtrate add solution of basic lead acetate, which gives a further precipitation of lead taurocholate."—[Chemical Physiology, Long, p. 119.]

(*c*) *Gmelin's test for bile pigments.*—To a few cubic centimeters of strong nitric acid in a test tube carefully add dilute bile. At the junction of the liquids a play of colors, green, blue, violet, red and yellow, will be noted; the green being next to the bile and the yellow next to the acid. This delicate and most reliable test may be applied to any liquid suspected of containing bile.

(*d*) The reaction of bile is found to be distinctly alkaline.

3. *Experiments and Observations.*

a. The action of pancreatic juice upon foods.

(1) To raw or cooked starch add in one beaker aqueous extract of pancreas (a); in another add artificial pancreatic juice (b); place the mixtures in the incubator; after a short time test for reducing sugar.

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*For description of operations for the establishment of gastric fistulæ, bilary fistulæ and pancreatic fistulæ, see Hand-book for Physiological Laboratory, Sanderson, pp. 475-517.

Pancreatic juice contains an amylolytic ferment.

(2) Subject fibrin to the action of both of the pancreatic preparations.

Pancreatic juice contains a proteolytic ferment.

(3) Boil fresh milk and mix it with an equal bulk of the aqueous extract of pancreas and put the mixture into the incubator. Put also into the incubator boiled milk diluted with an equal volume of distilled water. The milk which is mixed with pancreatic juice will curdle much sooner than the other.

Pancreatic juice contains a milk curdling ferment.

(4) Mix 5 or 6 c. c. of neutral olive oil with an equal volume of aqueous extract of pancreas; shake the mixture vigorously.

No emulsion is formed. Place one-half of the mixture in the incubator. After a few hours any undigested oil may be emulsionized on shaking, or fresh oil may be emulsified. Explain.

(5) To the second part of the mixture add 3 c. c. bile; shake the mixture vigorously. A good emulsion is formed. How is this emulsion formed? What factor of an emulsion does the bile add? What is the relation of experiment (5) to experiment (4)?

Pancreatic juice contains a fat-splitting ferment whose action liberates fatty acids.

(6) To starch paste add several volumes of dilute bile. Result?

(7) To fibrin add dilute bile. Result?

(8) To oil which contains free fatty acid add bile; shake the mixture vigorously; Result?

(9) To neutral oil add bile; shake the mixture vigorously. What is the result? Allow the mixture to stand in the incubator. After several hours shake the mixture.

Is an emulsion formed?

(10) Summarize the results of the foregoing experiments, formulating a series of conclusions regarding the action of pancreatic juice; the action of bile and their combined action on each class of food.

XLIII. Absorption.

Physiologists have entertained the hope that all the phenomena of absorption of diffusible substances could be eventually explained by the laws of physics. That hope has practically given place to the conviction that however important it may be to the animal economy to produce, in its digestive processes, diffusible products, these products do not pass through the epithelial lining of the alimentary tract at the rate or in the proportions that would be observed in the dialyzer. This need occasion no surprise; in one case we have to deal with living, active cells, in the other with dead tissue.

Living cells of muscle-tissue or of gland-tissue have the power of *selecting* from the tissue plasma such materials as are needed for the replenishment of their substance. Not only does the animal select what shall be taken into the alimentary tract but the epithelial lining of that tract seems to select what shall be absorbed and to absorb it according to laws which conform only in a most general way or which may not conform at all to the laws of osmosis. In order, however, to understand the current literature on the subject of absorption it is necessary to be familiar with the terminology and laws of osmosis and dialysis. To that end the student may profitably perform for himself a few simple experiments preliminary to more complex ones which the demonstrator may suggest or may perform for the class.

1. *Appliances and Materials.*—Six dialyzers complete, including outer receptacles and supports; 2 or 3, 100 c. c.,

evaporating dishes; distilled water; sodium chloride; alcohol; egg; mercury manometer.

2. *Preparation.*

(1.) Fit four of the dialyzers with membrane of pig-bladder. The bladders should be carefully selected as to uniformity in thickness, and should be soaked for an hour or more in water before being stretched upon the dialyzers. The membrane should be stretched as nearly uniform as possible upon the four dialyzers. Fit one dialyzer with parchment paper such as is frequently used for this purpose. Furnish one dialyzer with some other animal membrane e. g., a cow's bladder or a rabbit's cæcum.

(2) Prepare dilute egg-albumin by adding to strained undiluted albumin about 9 volumes of distilled water.

3. *Experiments and Observations.*

(1) Salt, in saturated aqueous solution may be put into a dialyzer. So adjust the apparatus that the water in the outer receptacle shall be on a level with the solution in the vertical tube of the dialyzer. How much does the water rise in the tube? What degree of positive pressure within the dialyzer does that represent? How much pressure per unit area, measured with a mercury manometer will it be necessary to produce within the dialyzer to stop the increase of the volume of its contents? (*Endosmotic pressure.*) Will that amount of pressure prohibit diffusion between the liquids?

(2) After osmosis has been allowed to take its unimpeded course for, say, one hour, starting with a 20 per cent. solution of NaCl within and distilled water without the dialyzer, note the height of the water in the tube and compute the number of grammes of water which have entered the dialyzer. Determine how

much NaCl has passed out of the dialyzer. An easy and sufficiently accurate method is to evaporate to dryness all, or a known proportion of the liquid in the outer receptacle, and weigh the dry salt remaining. How many grammes of water enter the dialyzer for each gramme of salt that leaves? (*Endosmotic equivalent.*)

(3) Is the endosmotic equivalent constant for salt and water? (*a*) Is it the same for different strengths of the salt solution, i. e., for 10% or 1% as for 20%? (*b*) Is it the same for two hours or four hours as for one hour?

(4) Fill with 10% glucose three dialyzers provided with three different kinds of membrane. Does osmosis take place at the same rate in all three dialyzers? What is the endosmotic equivalent for glucose?

(5) What is the endosmotic equivalent for dilute egg albumin? When albumin is injected into the colon it is readily absorbed as albumin, there being no digestive changes in it.

(6) Fill a dialyzer with equal parts of 10% glucose and 10% NaCl. At the end of a convenient period, 2–6 hours, determine whether these substances have diffused according to their own endosmotic equivalents, i. e., independent of each other, or have they been influenced the one by the other?

(7) Fill a dialyzer with alcohol. Which way does the osmotic current flow?

(8) In the above experiments water has uniformly passed into the dialyzer.* If pure water be taken into an empty stomach would one expect it to be readily absorbed?†

*If alcohol be taken into the stomach it is not diluted with water drawn from the tissue, but it is rapidly absorbed.

†Water is absorbed slightly, if at all, through the walls of the stomach.

F. VISION.

XLIV. Dissection of the appendages of the eye.

1. *Appliances.*—Fresh ox-eyes, including as much of the appendages as possible; physiological operating case; dissecting boards and pins, such as used for frogs; dog, cat or rabbit; bone forceps; injection mass; syringe.
2. *Dissection.*—Follow Gray; or Quain, Vol. III., Part III.
   (1) Before fixing the eye to the board make a careful examination of the organ.
   (*a*) Trace the *conjunctiva*, describing its *ocular* and its *palpebral* portions. Describe the *plica semilunaris* and the *caruncula*. Do these two tissues have the same relative size in man and the ox? Find and describe the *puncta lachrymalia*. Find and describe the openings of the *lachrymal ducts*. How many are there? Enumerate the conjunctival landmarks which determine the inner from the outer side of the eye. Enumerate the conjunctival landmarks which determine the superior aspect of the eye. Is the eye which you have a right or a left one?
   (*b*) Observe the appendages of the eye. Do you find a remnant of the *levator palpebræ* muscle? Find the *tarsal cartilages* and the remnant of the *orbicularis palpebrarium muscle*. Find openings of the *meibomian*

and of *sebaceous glands*. Find and describe the *lachrymal* gland as to *location* and *size*.

Find the cut-off ends of the *recti* and *oblique muscles* of the eye.

Describe the location of the *optic nerve* with respect to the cornea.

What traces have you found of the *capsule of Tenon*?

Enumerate the new landmarks which determine the superior aspect of the eye; the internal aspect. Are these extra landmarks sufficient to determine whether the eye which you have is a right or a left one?

(2) Fix the eye to the board with corneal surface down, pinning down flaps of the conjunctiva for support.

(*a*) Dissect out the four *recti* and the two *oblique* muscles. One will find in the ox a rather heavy retractor muscle in close relation to the optic nerve. This should be left undissected until the other muscles are demonstrated.

(*b*) Trace further the intricate loculi of the *capsule of Tenon*.

(*c*) Carefully separate from the eyeball all connective and adipose tissue.

(3) Remove the retractor muscle of the ox eye in process of dissection, taking care not to sever any important blood vessels or nerves.

(*a*) Locate and describe the *venæ vorticosæ*. How many are there?

(*b*) Find the *anterior ciliary arteries*. How many can be found?

Describe their relation to the tendons of insertion of the recti muscles. What tissues do they supply?

(*c*) Find the two *long ciliary arteries*.

(*d*) Locate and enumerate the *short posterior ciliary arteries.*

(*e*) Dissect out the *ciliary nerves.* What tissue do they supply?

(4) Let one number of the division dissect, for demonstration, the orbital muscles of a dog, cat or rabbit. To facilitate the dissection fix the animal with dorsum up, and remove with bone forceps the upper and outer walls of the orbit.

(5) Let one member of the division inject, with carmine or vermilion mass, the internal carotid of a dog, cat or rabbit, and dissect out for demonstration the *ocular branches* of the ophthalmic artery.

XLV. Dissection of the eyeball.

1. *Appliances.*—The eyes, already partly dissected, which have been kept in an ice chest; physiological operating case.

2. *Dissection.*—*a. Anterior dissection:* Fix the eye to the board, cornea upward, using the dissected muscles as guys.

   (1) Describe the *cornea* as seen from the front. Does the radius of curvature of the lateral meridian seem to be the same as the radius of curvature of the vertical meridian? With heavy scissors remove the cornea, leaving a margin of one-eighth inch anterior to its junction with the iris.

   Examine the cut surface of the cornea with a lens.

   (2) Through the elliptical opening thus made examine the iris as to texture, etc.

   (3) Holding the margin of the cornea with strong forceps, carefully dissect the sclerotic coat from the choroid for about one-eighth of an inch posterior to the angle of the anterior chamber. Locate four points in the margin from which incisions may be made antero-posteriorly between the insertions of the recti muscles. From the points located make the incisions posteriorly as far as the equator of the eyeball. Dissect each flap from the underlying choroid; remove the pins which fix the recti muscles, and through traction draw the flaps back; fix.

   (*a*) Make a drawing of the choroid with its irideal and ciliary portions thus exposed.

(*b*) Locate, if possible, the course and distribution of nerves and blood vessels.

(4) With fine forceps grasp the margin of the iris and with fine scissors cut out a sector limited posteriorly by the ciliary body.

(*a*) Study the boundaries of the *posterior chamber*.

(*b*) Find fibers of the *suspensory ligament*.

(*c*) Describe the anterior surface or the ciliary processes.

(5) Make a circular incision with small scissors severing the choroid and retina at about the line of the *ora serrata*. Lift off from the dense vitreous humor the whole ciliary apparatus and lens, place them, anterior surface downward, upon a plate.

(*a*) Describe the posterior aspect of the ciliary processes.

(*b*) Describe the lens minutely, as viewed externally.

(*c*) Make a section of the lens, describe its appearance. Is the capsule discernible?

(6) Describe the retina as seen through the vitreous humor.

(*a*) Locate the entrance of the *optic nerve*.

(*b*) Can the *fovea centralis* be located?

(*c*) Can the course of the retinal vessels be followed?

2. *b. Posterior dissection.*

(7) Let one member of the division remove the posterior half of the sclerotic coat, after first fixing the eye with cornea downward, using the recti muscles, in this case also, for guys.

(*a*) Note the *venæ vorticosæ*.

(*b*) Follow the ciliary nerves from their entrance into the eyeball, along their course between the sclerotic and choroid coats.

(*c*) Do you find the long ciliary arteries, or the posterior ciliary arteries ?

(8) Remove the choroid carefully.

(*a*) Note the character of its tissue, its vascularity and its rich pigmentation.

(*b*) Describe the retina as seen from this direction. Its pigmented layer has probably come away with the choroid.

(9) Remove the posterior half of the vitreous body together with the retina.

(*a*) Make a drawing of the posterior surface of the lens, suspensory ligaments and ciliary processes as shown posteriorly.

(10) Remove the remnant of the vitreous body; sever the fibers of the suspensory light; lift out the lens.

(*a*) Describe the ciliary body and the iris thus held in their normal relations by the supporting sclera.

XLVI. Physiological optics. a. Determination of indices of refraction of water and of glass. b. Determination of focal distance of lenses. c. Verification of formula: $\frac{1}{f} + \frac{1}{f'} = \frac{1}{F}$. d. A simple dioptric system.

a. Determination of the indices of refraction of water and of glass.

1. *Appliances.*—Apparatus for determining the index of refraction; a deep flat-bottomed water pan; a cube of glass 4–6 cm. in linear dimensions and polished on at least two opposite sides. The two polished sides must be absolutely parallel, whether the other sides are parallel makes no difference; centimeter rule and dividers.

2. *Preparation.*—A very convenient and sufficiently exact apparatus for making the required determination may be readily made as follows:

   (1) Take a carpenter's tri-square, constructed wholly of iron; from the angle x (Fig. 26), where the graduated limb joins the body, measure off centimeters upon the inner surface of the body and cut them in with a file.

   (2) Locate on the inner edge of the graduated limb any point, as y, 6 to 9 centimeters from the point x. With files remove about ½ centimeter of the edge as indicated in the figure, cutting deeply at z, so as to leave a slender point at y as indicated.

   (3) Drill a hole in the inner surface of the body at o; fit and drive a heavy brass or iron wire into this; sharpen the upper end of the wire. The length of the wire above the body must be two or three centimeters

greater than the distance x y. Bend the point over so that the distance o p shall equal x y.

3. *Experiments and Observations.*—Place the instrument in the water pan; fill the pan, so adjusting it that both points p and y will just touch the water, or rather *almost* touch the water, for the surface of the water at y must be absolutely plane. If the point touch it the surface will not be plane.

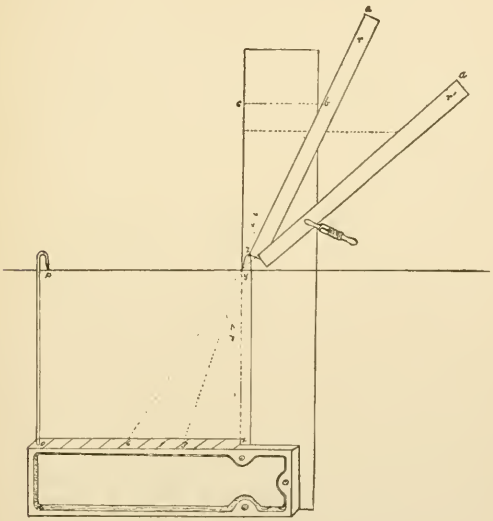


FIG. 26.

FIG. 26. A contrivance for use in determining the refractive indices of water and of glass.

(1) (*a*) Bring a small rule (r) into position and clamp it to the limb of the instrument by means of heavy serre-fine forceps. So adjust the rule that as one sights along its upper edge the points a, y and 3 seem to lie in one and the same straight line. Lift the ap-

paratus out of the water and lay it upon the table, taking care not to disturb the adjustment.

(*b*) With dividers measure the distance from the point y to line 3. This is the radius. Determine the point where the circumference would cut the upper surface of the rule, say point b.

(*c*) From this point determine the perpendicular distance to the edge of the limb at c.

(*d*) The line c y x is a normal to the surface of the water at the point y. The angle i is the angle of incidence; the angle r is the angle of refraction. Imagine a circle whose center is at y and whose circumference passes through b and 3. The line b c is the sine of the angle of incidence. The line x 3 is the sine of the angle of refraction.

(*e*) What is the ratio of sin i to sin r, or $\frac{\sin i}{\sin r} = ?$

(2) In the same manner determine the ratio of the sines of these angles when the rule is so adjusted as to bring a′y 6 in apparently one straight line. What is the ratio of sin i′ to sin r′? or $\frac{\sin i'}{\sin r'} = ?$

(3) If the instrument has been carefully constructed and if the determination has been made with sufficient care, the ratios will be found to be practically equal, i. e., $\frac{\sin i}{\sin r} = \frac{\sin i'}{\sin r'}$. What is the constant ratio in the case of water? This constant ratio is called the index of refraction, and is conventionally represented by μ.

For water, $\mu = \frac{\sin i}{\sin r} = \frac{4}{3} = 1.333.$

(4) To determine the index of refraction of glass proceed as in the case of water. Set the instrument upon the table; the block of glass may be placed upon the body of the instrument, the polished surfaces being placed above and below. If the distance be-

tween the polished surfaces is not equal to x y, a point y′ may be located on the upper surface near the edge of the glass block by making a dot with ink where the line y x cuts the upper surface of the block. This line is the normal.

What is the index of refraction of the glass block furnished by the demonstrator?

b. The determination of the focal distance of lenses.

By means of a spherometer the radius of curvature (r) of a lens may be determined.*

If one knows the radius of curvature of a lens and the index of refraction of the material of which the lens is made he may compute the focal distance by using the formula (1) $F=\frac{r}{\mu-1}$ for plano-convex lenses, or (2) $F=\frac{r}{2(\mu-1)}$ for bi-convex lenses. But there is an easier and more direct method of determining the focal distance of a lens; namely, by direct experiment.

1. *Appliances.*—An instrument such as is used in physical laboratories for the same purpose or such a one as is described under 2; several lenses ranging from 5 cm. to 50 cm. in focal distance.

2. *Preparation.* — A most satisfactory apparatus for this purpose may be made by any student or demonstrator in three or four hours. From thin pine boards construct a simple box about 10 cm. square in cross section by 50 cm. in length. One end of the box should be closed with a tightly stretched oiled paper for a screen, while the other end may be closed with the same material of which the rest of the box consists, the center of the end having a circular aperture one or two centimeters in

*[$r=\frac{l^2}{6a}+\frac{a}{2}$, when a=spherometer reading, and l=the length of one side of the equilateral triangle determined by the legs of the spherometer.]

diameter. The bottom of the box is constructed as follows: (See Fig. 27.) Cut through the middle of the bot tom a slot about 0.5 cm. wide and 45 cm. long. Make a lens carrier of wood as indicated in the figure (Fig. 27, C. & C'.). The saw groove in the top of the carrier serves to hold the lens. If, however, the lenses to be used in the apparatus be not provided with rims and

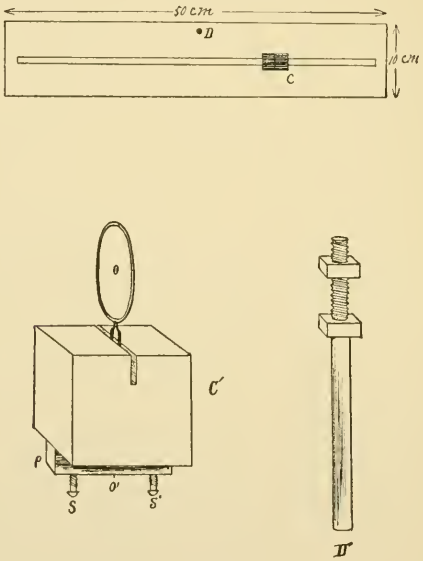


Fig. 27.

Fig. 27. Showing parts of apparatus for determining the focal distance of lenses. For construction of the apparatus, see **XLVI=b=2.**

rings the demonstrator can readily contrive a means of holding them in place. In any case they should be so held that the plane of the lens is perpendicular to the axis of the box, and that the center of the lens (o) is virtually over a fixed line (o') drawn transverse to the

axis of the lens carrier. The screws S and S′ serve the double purpose of protecting the projection (p) from splitting off and of affording handles by which the carrier may be slipped along the groove. Along one edge of the groove on the outer surface of the bottom make a centimeter scale carefully with a sharp hard lead pencil. The scale should have its zero point in the plane of the screen. At the point D fix a shaft (such a one as shown in Fig. 27, D′), which shall extend several centimeters below the bottom and set perpendicular to it. The shaft may be fixed in a universal clamp-holder and the whole supported upon a heavy support. By adjusting the clamp-holder the apparatus may be directed toward any desired object. Make a cover to the box, and blacken the whole inside.

3. *Observations.*—Fix a lens in place; close the box; direct its axis toward some well illuminated distant object; grasp the handles of the lens carrier and move it to a position which gives upon the screen a sharply defined image of the object in the field. One has only to read the position of the transverse line of the carrier on the centimeter scale to have the focal distance of the lens; i. e., the distance at which parallel rays are focused.

c. Verification of the formula $\frac{1}{f} + \frac{1}{f'} = \frac{1}{F}$.

A second method of determining the focal distance of a lens depends upon the relation of the distances of the conjugate foci to the general focal distance: This relation may be expressed thus: *The sum of the reciprocals of the conjugate foci is equal to the reciprocal of the focal distance.* $\frac{1}{f}+\frac{1}{f'}=\frac{1}{F}$. Now when a lens throws upon a screen the image of an object it is evident that the distance of the object (o) represents one and the distance of the image (i) represents the other of these conjugate focal distances; so one may

say: *The reciprocal of the distance of the object from the lens* ($\frac{1}{o}$) *plus the reciprocal of the distance of the image* ($\frac{1}{i}$) *equals the reciprocal of the general focal distance* $\frac{1}{F}$: *thus* ($\frac{1}{o}+\frac{1}{i}=\frac{1}{F}$). This formula enables one to compute the focal distance after first determining by experiment the values o and i. Inasmuch as the student has already determined the focal distance (F) and may not have made the rather extended computation incident to the derivation of the above most valuable formula it is considered that the most profitable course to pursue at this point is the verification of the formula.

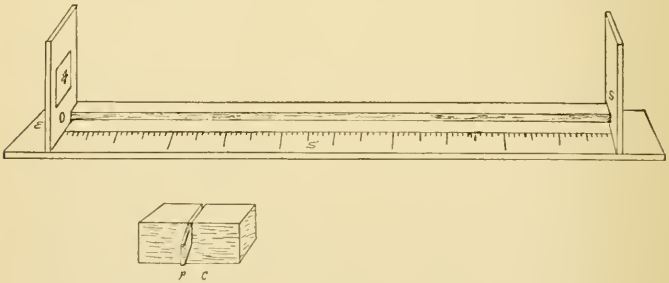


Fig. 28.

Fig. 28. An apparatus for determining the conjugate focal distance For description, see c=1.

1. *Apparatus.*—To that end one may construct a simple apparatus (Fig. 28). For the determination of the focal distance it is usual to have both object and lens movable. For our purpose this may be dispensed with as it lends little to the reliability of the result and detracts much from the simplicity of the apparatus. Upon a thin board as a base fix an upright piece near one end of the base, whose inner surface may be painted white and serve as a screen (S). Near the other end fix a

second upright piece having in its center a large hole. Over this hole, on the inner surface of the upright, fix a sheet of lead or of copper in which some figure has been cut (o). Construct a lens carrier (c), whose pointer (p) will indicate upon the scale (s′) the position of the center of the lens. The use of the instrument will be somewhat facilitated if the distance between the surface of the screen and the surface of the lead or copper be purposely made exactly 100 cm. In addition to the above apparatus one needs the lenses whose focal distance he has determined. He needs also a lamp or candle to place behind the metallic screen at e.

2. *Experiments and Observations.*—Place a light behind the metallic screen; it shines through the figure cut through the screen. This figure is the *object.*

(1) (*a*) Place a lens in the carrier and so adjust it that the plane which it represents is perpendicular to the axis of the instrument and its center is in the same perpendicular plane with the index (p) of the carrier.

(*b*) Slide the carrier along the base until the object is sharply focused upon the screen.

(*c*) Read from the scale the distance of the lens from the image (i). If the instrument is made just 100 cm. between screen and object, then the difference between 100 and the reading will be the distance of the lens from the object. Is the image erect or inverted? Explain the phenomenon, drawing geometric figure.

(2) Study the general formula:

(*a*) $\frac{1}{o}+\frac{1}{i}=\frac{1}{F}$.

(*b*) $F=\frac{o\,i}{o+i}$; but $o+i=100$; therefore

(*c*) $100\,F=o\,i$.

From this form of the statement it is evident that the

lens will throw a distinct image in either one of two positions. Demonstrate it experimentally.

(3) Determine o and i for each lens and substituting their values and that of F previously determined, verify the equation. A moderate deviation may be expected, due to errors in the apparatus and in the observations.

(3) *Problems.*

The value of the formula $\frac{1}{o}+\frac{1}{i}=\frac{1}{F}$ is so great and its application so frequent that the student should thoroughly familiarize himself with the properties of lenses as revealed in this formula.

Solve the following problems:

(1) When the object is twice the focal distance, what is the distance of the image?

(2) When the distance of the object is greater than 2F, how does the distance of the image compare with 2F?

(3) When the object is at a very great distance ($o=\infty$) at what distance will the image be formed?

(4) What is the maximum focal distance that may be determined or verified with the above described apparatus? Discuss methodically.

d. A simple dioptric system.

The simplest dioptric system is one in which the ray passes from one medium into a second medium of different refractive index, the surface of separation of the two media being a spherical surface. In the accompanying figure (Fig. 29 A) the spherical surface s′sps″ separates the medium M, whose refractive index is 1.000, from the medium M′, whose refractive index is 1.500.

Note the following *cardinal points* of a *simple dioptric system.*

The center of curvature of the spherical surface (n) in the *nodal point.*

That radius which is the center of symmetry of the dioptric system (e. g., n—p.) is called the *principal axis* of the system. In this axis lie the *first* and *second principal foci*, f and f′ respectively. The point where the optical axis cuts the spherical surface (p) is called the *principal point.* The plane tangent to the spherical surface at this point is the *principal*

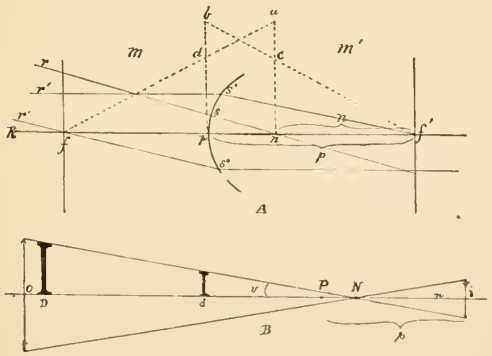


Fig. 29.

Fig. 29. A. Showing the cardinal points of a simple dioptric system. n, nodal point; R p n, principal axis; p, principal point; f, f′, principal foci.

Fig. 29. B. Showing the relation of the visual angle, v and the size of object and image to values p and n.

plane. Planes perpendicular to the optical axis at f and f′ are called the *first* and *second principal focal planes* respectively.

Problem. Given the radius of curvature and the index of refraction to locate upon the principal axis the principal foci.

Neumann has given the following construction:

(1) Erect at n and p perpendiculars to the principal axis.

(2) Lay off, upon each, the two indices of refraction of the two media, measured from the origin of each perpendicular, in the same linear units used in measuring the radius. In the figure let n c and p d represent the index of refraction of the medium M, and n a and p b the index of refraction of medium M′. The continuation of line a d cuts the principal axis in the point f, the first principal focus, while the line b c cuts it in the point f′, the second principal focus. The geometrical figure shows the following important properties of the dioptric system:

I. The distance from the first principal focus to the principal point equals the distance from the second principal focus to the nodal point.

(1) Mathematically expressed: pf=nf′.

II. The ratio of the second focal distance (pf′) to the first (pf) is equal to the ratio of the index of refraction of the second medium (M′) to that of the first (M).*

(2) Mathematically expressed:—pf: pf′=μ: μ'. But pf=nf′; substitute this value in the second equation,—

(3) . . . . nf′: pf′=μ: μ'; assume medium M to have an index of refraction μ=1.

(4) nf′: pf′=1: μ'.

(5) pf′=nf′×μ'; or more concisely

(5′) p =μ'n. (See p and n in Fig. 29. A.)

This derived property of the construction merits a separate formulation.

*Refraction and Accommodation of the Eye.—Landolt, p. 85.

III. The distance from the second principal focus to the principal point equals the product of the distance from that focus to nodal point multiplied by the index of refraction of the second medium ($p = u'n$).

Note in addition the following facts regarding the effect of such a dioptric system upon light.

1st. The ray rs, meeting the spherical surface perpendicularly, will not be refracted at s, but will pass on through the nodal point.

2d. The ray r's', parallel to the principal axis in the first medium is refracted at the spherical surface and cuts the principal axis at f',—it passes through the second principal focus.

3d. The ray r''s'', cutting the principal axis at f in the first medium (M), is refracted at s'' and traverses the second medium parallel to the principal axis.

XLVII. Physiological optics, applied. a. The application of the laws of refraction to the mammalian eye. b. To locate in the mammalian eye the cardinal points of the simple dioptric system.

The dissection of the ox eye revealed several refractive media (cornea, aqueous humor, lens, and vitreous humor) and several curved surfaces bounding these media. In determining the focal distance of a lens one must know the radius of curvature and the refractive index. In determining the focal distance of a system of refractive media and surfaces one must know (1) the radius of curvature of each surface, (2) the refractive index of each medium, and (3) the location of their cardinal points upon the principal axis of the system.

The mammalian eye receives its light through media and surfaces, as indicated in the following table:

MEDIA.	INDEX OF REFRACTION.	SURFACE.	RADIUS.
Air.	1.000	.....	... .
Tear Film.	1.3365	Over Ant. Surf. Cornea.	7.829+ cm.
Cornea.	1 3367	Ant. Corneal Surface.	7.829+ cm.
Aq Humor.	1 3365	Post. Corneal Surface	7.829— cm.
Lens.	1 4371	Ant. Surface.	10 0 cm.
Vit. Humor.	1.3365	Post. Surface.	6 0 cm.

This array of media and surfaces would seem to make a problem too intricate to solve with the means at our disposal. Notice, first that the tear film and the ant. and post. corneal surfaces have the same radius of curvature;

i.e., though curved surfaces they are parallel and form a case under the following theorem: "If a ray pass from any medium through a denser medium which is bounded by two parallel planes it emerges from the denser medium in a line parallel to its course before entering that medium." It is customary at this point to take the anterior surface of the cornea as the first refractive surface and $\mu = 1.3365$.

Notice that the index of refraction of the aqueous humor and vitreous humor are the same. It is now evident that we have to deal with three media [air, aqueous or vitreous humor, and lens], with three surfaces [ant. corneal surface, ant. and post. lens surface], whose radii are 7.829, 6 and 10 respectively. But even this great step toward simplifying the problem leaves us with a long road before us unless we can find a short cut. "It has been shown mathematically that a complex optical system consisting of several surfaces and media, centered on a common optical axis, may be treated as if it consisted of two surfaces only." [Text-book of Physiology—Foster, 1891—vol. IV., pg. 9.] The location of these surfaces and the cardinal points are given as follows by Landolt :

A. The normal eye.

The point r (Fig. 30.) where the principal axis cuts the cornea is 22.8237 mm. from the second principal focus f′ (the retina); c, the center of curvature of the cornea; s, the point where the optical axis cuts the anterior surface of the lens, is 3.6 mm. from r, the point where the optical axis cuts the posterior surface of the lens 7.2 mm. from r; l, the center of curvature of ant. surface of lens; l′, the center of curvature of posterior surface of lens.

B. The accurate mathematical reduction.

The reduction referred to in the text above is represented by the two refractive surfaces with nodal points n and n′

radii of 5.215 mm. each and cutting the optical axis at p and p′, located 1.7532 mm. and 2.11 mm. respectively from r.

C. The final approximate reduction.

Note that p is less than 0.36 mm. from p′. One may assume *one nodal point N*, and *one refracting surface* between the computed ones, cutting the principal axis at P, and introduce an error too slight to consider. But this brings

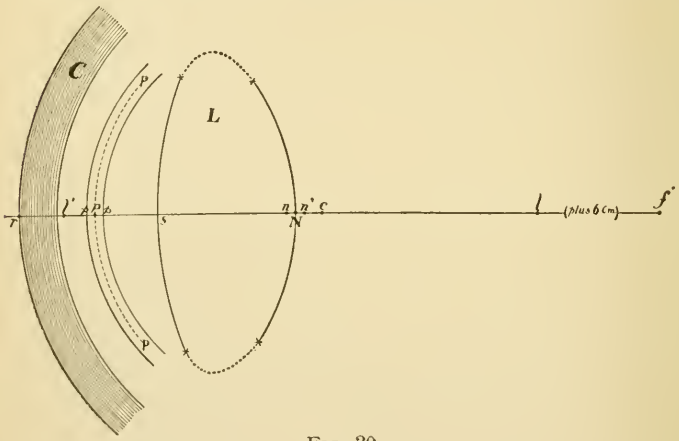


Fig. 30.

Fig. 30. Showing the mathematical features of the *reducea eye*. For detailed explanation of the figure see text *A*, *B* and *C*. The figure is multiplied by five in its linear dimensions. [Errata: For 6 cm read 3 cm.]

us back to the *simplest possible dioptric system*, already described on pg. 206 *et. seq.*

All of the properties of that simple dioptric system are possessed by the normal mammalian eye.

b. To locate, experimentally in the mammalian eye, the cardinal points of the simple dioptric system.

1. Appliances and Materials.—A white rabbit; support with universal clamp-holder and small cork-lined burette

clamps; meter stick or tape; steel or ivory rule, with millimeters subdivided if possible, hand lens, fine dividers with needle points; bone forceps; NaCl 0.6%; camel's hair pencil; absorbent cotton.

2. *Preparation.*—(1) *Mathematical.* (See Fig. 29 B.) We wish first to locate the nodal point in a rabbit's eye. Represent the distance from the retina to the nodal point by n, the distance from the object to the image by d, the vertical dimension of the object by o, the same dimension of the image by i. From the similar right triangles of the figure one may write:

$$(1)\ o : i = d - n : n;$$

$$(2)\ on = id - in;$$

$$(3)\ n = \frac{id}{o+i};$$

Under the conditions of the experiment i is so small compared with o that it may be ignored in the denominator, and we may use the equation:

$$(4)\ n = \frac{id}{o}.$$

(2) *Arrangement of Apparatus.*

(*a*) A convenient *object* to observe is a well-illuminated window, or one sash of a window; measure the vertical distance *between* the horizontal strips of the sash.

(*b*) Arrange three or four tables end to end in a line perpendicular to the plane of a window. On the table lay off from the plane of the window the distances 4, 4.5, 5, 5.5 and 6 meters.

3. *Operation.*

(1) Remove an eye from the rabbit which had been chloroformed some time before and suspended by the anterior limbs.

(2) Dissect from the eye, especially from the posterior

aspect of it, all of the areolar connective tissue, muscle tissue, etc., down to the glistening smooth sclera.

(3) Wrap around its equator a band of absorbent cotton wet with normal solution.

(4) Fix the eye in the clamp with its axis transverse to the axis of the clamp, taking care to exert just enough pressure to prevent the eye from falling on being touched, *but not enough to distort it.*

(5) Fix to the clamp a thread with a bit of lead to serve as a plumb line.

4. *Observations.*

(1) Adjust the support so that the eye is directed toward the object and the image is located approximately symmetrically about the fovea centralis, and the plumb line over the mark 4 meters. With the fine dividers measure in the image the distance between those points which were chosen as the limits of the object. The value of this measurement may be read to tenths of millimeters by laying the divider points upon the steel rule and reading with the hand lens.

(2) Make similar observations at 4.5 m., 5 m., 5.5 m., and 6 m. Each observation should be made three or four times and the average taken.

(3) Record these averages in a table ruled with columns for the values d, o, i, n and p.

(4) Calculate for column n the values obtained by substituting, in the formula $n=\frac{id}{o}$, the values observed in (1) and (2). What is the value of n?

(5) Measure the antero-posterior diameter of the eye. How far anterior to the posterior surface of the sclera is n located? How far from the surface of the cornea? How does the ratio of these two quantities differ from that given above for the human eye?

(6) Locate the position of the principal point or the

point where the ideal refracting surface of the eye cuts the optical axis, by applying the formula:

$$p = \mu n.$$

Assuming for μ the value which it has been calculated to have in the human eye (1.3365 Landolt, p. 86), how far is this point posterior to the anterior surface of the cornea? How does your result compare with that for the "reduced human eye?"

(7) Is the image erect or inverted? Explain the phenomenon?

(8) Move the eye to within one meter of the object. Note that a fairly clear image may be thrown upon a posterior segment of the sphere, which is many hundred times the area of the fovea centralis.

(9) If a fine sharp needle be thrust through the eyeball, following a course perpendicular to the optical axis and cutting it at *n*, what relation would this needle have with the lens? Would it be tangent to the lens; would it enter the lens or would it pass free of its posterior surface?

(10) If a similar experiment were performed with reference to the point p, what relation would the needle have to the anterior surface of the lens?

For these experiments the eye may be frozen after the introduction of the needle and a vertical longitudinal section made.

XLVIII. Accommodation and convergence.

In the above experiment with the excised rabbit's eye one notices a marked blurring of the image when the eye is brought near the object. Though the definition of the image is sharp at 5–6 meters or beyond, at 2 or 3 meters the outlines are hazy. The normal living eye is, however, able to give one *the sensation of a clear image at any distance from several inches to several miles.* That there is actually a sharply defined image upon the retina when the normal mind has the sensation of such an image there is no doubt.

One knows from his experience with optical instruments that they must be readjusted for each distance if they are to yield a sharp image for each distance.

The same thing is true in the case of the organic optical instruments with which one perceives the form, color and space relations of the objects of his environment. *The functional adaptation of the visual organs to distance is called accommodation.*

a. Accommodation.

Experiments and Observations.

(1) Take a sharp pointed pencil or similar object in each hand; hold the upturned points in the line of direct vision before the eye, one point being about 25 centimeters distant from the eye and the other at arm's length; make the observations with *one* eye, the other being closed or screened.

(*a*) Focus upon the near point. Is the image of the distant point clear?

(*b*) Focus upon the distant point. Is the image of the near point clear?

(*c*) While the eye is focused steadily upon the near point bring the distant point slowly up to a position beside the near point. One of the images is transformed from an ill-defined one to a clearly defined one. Which image is it? Does one note a similar change in the definition of the image when he moves the near point out to position beside the distant point while focusing steadily at the latter?

(*d*) Sum up the results of the experiment into a concisely formulated statement.

(2) Holding the two points side by side at a distance of 30 centimeters note that the points appear equally well defined.

(*a*) Direct the eye steadily at one of the points while moving the other one nearer to the eye. Note the number of centimeters which it advances toward the eye before the outlines become ill-defined. Reverse the act, moving the point back to its original position beside the stationary point, noting that the image of the receding point remains clear.

(*b*) Continue to carry it farther from the eye, noting that after it has been carried beyond the unmoved focused point a certain distance the outline becomes again ill-defined. Note the number of centimeters between the two points in this position.

(*c*) Make a similar experiment, using 50 cm. for the distance of the stationary point, and note the centimeters between the points at the limits of clear definition. In this way one may observe and measure the depth of focus of the eye.

(*d*) Is the depth of focus greater at 30 cm. or at 50 cm.?

(*e*) Is the depth of focus greater at 100 meters than at one meter? Demonstrate and explain.

(3) *Determination of the near point or "punctum proximum."* Determine the distance from the eye of the nearest point at which a pencil point or needle may be perfectly clearly seen. The exact location of the near point may be more satisfactorily determined if one look at the object through two holes, 2 mm. apart, in a card. At this point the punctum proximum act of accommodation is brought most actively into play.

(4) Determination of the *punctum remotum.*

(*a*) Direct the eye toward some object not less than six meters away and describe to other members of the division the minute details of the object, such as slight irregularities of surface lines or other details. If an individual is able to convince his comrades that he can perceive, at this distance the minute details of objects he must be credited with normal vision. Inasmuch as he can also see with the usual distinctions more distant objects the *punctum remotum* is said to be located *at infinity;* or, to state it in another way, the eye is able, with suspended accommodation, to bring parallel rays to a focus upon the retina.*

(*b*) It frequently happens that the individual under observation fails to make out more than the merest outline of an object 6 meters away. Decrease the distance until he is able to perceive details seen by the majority of his comrades. If this distance has to be decreased to two or three meters the determination may be made more exact by resorting again to the needle and punctured card mentioned in (a), and carrying the needle away until it appears double.

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* It must be stated here that this experiment does not make it certain that the *punctum remotum* is not *beyond infinity!* In a subsequent lesson that point will be carried farther. We must be temporarily content with having it so far.

In recording the *punctum remotum*, write infinity (∞) for six meters or more and for any distance within that, record in meters and decimals thereof.

(5) How many meters from the punctum remotum to the punctum proximum in those cases where the punctum remotum is less than six meters?

(6) Observe the pupil closely while the subject directs the eye from a distant object to a near one. It contracts slightly. On *a priori* grounds this act of the iris is advantageous. Show from the standpoint of theoretical optics why it is advantageous.

(7) Observe from the side that when the act of accommodation takes place the iris at the edge of the pupil not only moves toward the center but advances noticeably toward the cornea. What could produce this?

(*a*) If the edge of the iris rests upon the lens capsule would it not be pushed farther toward the cornea incident to its contraction toward the center?

If the pupil contracted from a 3 mm. diameter to a 2 mm. diameter, how much would it be advanced incident to the normal curvature of the lens. Could this be detected by the method of observation which has been employed?

(*b*) Account for the forward movement of the pupillary edge of the iris during accommodation.

b. Adaptation of the eye for direction. Convergence.

Just as the eye possesses a mechanism by which it changes its refractive power for different distances, so it possesses a mechanism by which it may change the direction of its visual axis from one object to another or may follow the movements of objects within the range of vision.

1. Monocular fixation.—Let two individuals work together, one as subject and the other as observer. Let them sit

on opposite sides of the table. Let the subject close or screen one eye.

(1) Hold any object directly in front of the subject; let the subject keep his gaze continually fixed upon the object. Move the object quickly toward the subject's left, and note the fixation anew of the object in its new position. What muscle or muscles accomplished this act of monocular fixation?

(2) Move the object quickly in the opposite direction, then upward, downward and diagonally, noting the instantaneous adaption of the eye to the new direction, recording also the muscle or muscles involved in each act. Are all the movements apparently equally ready and exact?

(3) Bringing the object to a point directly in front, 1 m. distant, note through how great a lateral movement it may be carried without inducing any discernible change in the visual axis of the eye.

(4) Bring the object to the central position and move it very slowly outward in any direction, noting whether the changes in the direction of the visual axis are equally slow and regular.

2. *Binocular fixation, convergence.*

In the above experiments it was probably noted by both subject and observer that the closed or screened eye responded to every movement of the other eye.

(5) With both eyes open and fixed upon an object held directly in front at a distance of about 1 m., let the observer move the object quickly, then slowly, right, left, up, down, and around, and observe the continuous perfect fixation of the object with both eyes.

(*a*) What muscles are involved in following an object from one's right side to his left? In each other direction in turn?

(*b*) Do all of these muscles seem to act perfectly in all of the subjects examined? If not; describe any variation.

(6) *Convergence.* (*a*) Let the subject direct his gaze at the tip of the observer's ear, and without warning change his point of binocular fixation to some distant object in the same line of vision. What change in the eyes of the subject is noticeable by the observer? What muscles were involved in producing the change?

(*b*) Hold an object in front of the subject and 1 m. distant. Move it directly toward the subject's eyes and note the convergence of the lines of vision of the two eyes. What muscles perform the act?

(*c*) Through how short a distance may the object be moved in the direct line of vision without causing a discernible change of the angle of convergence of the two eyes.

(*d*) From the central, 1 m. position, carry the object to a point about ½ m. to the right, and ½ m. above the eyes of the subject. What muscles are involved in the act of convergence?

(*e*) Is the power of convergence apparently normal in all members of the class? If not, describe minutely any variations.

XLIX. Miscellaneous experiments.*

a. Scheiner's experiment.

(1) Prick two smooth holes in a card at a distance from each other less than the diameter of the pupil. Fix two long, fine needles or straws in two pieces of wood or cork. Fix the cardboard in a piece of wood with a groove made in it with a fine saw, and see that the holes are horizontal. Place the needles in line with the holes, the one about eight inches, the other about eighteen inches from the card.

(2) Close one eye, and with the other look through the holes at the *near* needle, which will be seen distinctly, while the far needle will be double, both images being somewhat dim.

(3) With another card, while accommodating for the *near* needle, close the right-hand hole, the right-hand image disappears; and if the left hand hole be closed, the left-hand image disappears.

(4) Accommodate for the *far* needle, the near needle appears double. Now close the right-hand hole, and the left hand image disappears; and on closing the left-hand hole, the right-hand image disappears. [Practical Physiology—Stirling.]

(5) Explain the phenomena, drawing figures which show just what must take place in the eye.

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*The miscellaneous experiments of Lesson XLIX have been taken from Stirling's Practical Physiology. The author takes this place and opportunity to acknowledge his indebtedness to Prof. Stirling.

(*b*) *Purkinje-Sanson's images.*

(6) In a dark room, light a candle and hold it to one side of the observed eye and on a level with it. Ask the person to accommodate for a distant object, and look into his eye from the side opposite to the candle, and three reflected images will be seen. At the margin of the pupil, and superficially, one sees a small bright *erect* image of the candle flame reflected from the *anterior surface of the cornea.* In the middle of the pupil there is a second less brilliant and not sharply defined *erect* image, which, of all the three images, appears to lie most posteriorly. It is reflected from the *anterior surface of the lens.* The third image lies toward the opposite margin of the pupil, is the smallest of the three, and is a sharp *inverted* image, from the *posterior surface of the lens.* Ask the person to accommodate for a near object, and observe that the pupil contracts, and the middle image—that from the anterior surface of the lens—becomes smaller and comes nearer to the corneal image. This shows that the anterior surface of the lens undergoes a change in its curvature during accommodation.

(7) Place in a convenient position on a table a large convex lens, supported on a stand. Standing in front of it, hold a watch glass in the left hand in front of the lens and a few inches from it. Move a lighted candle at the side of this arrangement, and observe the three images described above. Substitute a convex lens of shorter focus, and observe how the images reflected from the lens become smaller. [Practical Physiology—Stirling.]

(8) Explain the phenomena, using drawings.

c. The blind spot.

(9) *Marriotte's experiment.*—On a white card make a black

cross and a circle about three inches apart. Closing the left eye hold the card vertically about ten inches from the right eye and so as to bring the cross to the right side of the circle. Look steadily at the cross with the right eye, when both the cross and the circle will be seen. Gradually bring the card toward the eye, keeping the axis of vision fixed on the cross. At a certain distance the circle will disappear, *i. e.*, when its image falls on the entrance of the optic nerve. On bringing the card nearer, the circle reappears, the cross of course being visible all the time.

(10) *Map out the blind spot.*

Make a cross on the center of a sheet of white paper and place it on a table about ten or twelve inches from you. Close the left eye and look steadily at the cross with the right eye. Wrap a penholder in white paper, leaving only the tip of the pen point projecting, dip the latter in ink, or dip the point of a white feather in ink, and keeping the head steady and the axis of vision fixed, place the pen point near the cross and gradually move it to the right until the black becomes invisible. Mark this spot. Carry the blackened point still further outward until it becomes visible again. Mark this outer limit. These two points give the outer and inner limits of the blind spot. Begin again moving the pencil first in an upward and then in a downward direction, in each case marking where the pencil becomes invisible. If this be done in several diameters an outline of the blind spot is obtained, even little prominences showing the retinal vessels being indicated.

(11) *To calculate the size of the blind spot.*

Helmholtz gives the following formula for this purpose: When f is the distance of the eye from the paper, F

the distance of the second nodal point from the retina—usually 15 mm.—*d* the diameter of the sketch of the blind spot drawn on the paper, and D the corresponding size of the blind spot: $\frac{f}{F} = \frac{d}{D}$ or $D = \frac{Fd}{f}$.

d. The macula lutea or yellow spot. Maxwell's experiment, (12) Make a strong solution of chrome alum—filter it, and place it in a clear glass bottle with flat sides.. Close the eyes for a minute or so, open them, and while holding the chrome alum solution between one eye and a white cloud, look through the solution. An oval or round rose spot will be seen in the otherwise green field of vision. The pigment in the yellow spot absorbs the blue-green rays, hence the remaining rays which pass through the chrome alum give a rose color.

(13) Is it possible to calculate the size of the macula lutea?

e. Shadows of the fovea centralis and retinal blood vessels. Move, with a circular motion, a blackened card with a pinhole in its center, in front of one eye looking through the pinhole at a white cloud. Soon a punctated field appears with the outlines of the capillaries of the retina. The oval shape of the yellow spot is also seen, and it will be noticed that the blood vessels do not enter the fovea centralis. Move the card vertically, when the horizontal vessels are most distinct. On moving it horizontally, the vertical ones are most distinct. Some observers recommend that a slip of blue glass be held behind the hole in the opaque card, but this is unnecessary.

L. Perimetry.

In the foregoing experiments we have dealt exclusively with what is called *direct vision*, i. e., with phenomena involving the formation of a clearly defined image upon the *macula lutea*. Every one has noticed that outside the range of direct vision one may still get a pretty definite idea not only of form but of color as well. It is the purpose here to ascertain just how far this field of *indirect vision* extends in every direction from the visual axis; or, *to locate the perimeter of the field of indirect vision.* Various instruments have been devised—called *perimeters* to aid one in *perimetry*.

All of these appliances have for their object the mapping of the field. In all exact methods the map takes the form of a polar map, the pole corresponding to the point where the line of vision would pierce perpendicularly the plane of the map.

1. *Appliances.*—A perimeter, or ruled blackboard, Fig. 32; perimeter charts, such as shown in Fig. 33.

2. *Preparation.*—A very economical and exact perimeter may be constructed in the following manner:

Take a blackboard whose dimensions are abont 1 m. by 1.5 m. Locate a point 40 cm. from one end and 50 cm. from either side. Let this be the point of fixation or the point where the line of direct vision falls upon the surface of the board.

We propose now to draw upon the board a series of circles whose distance from one another shall represent an angular distance of 10°. Reference to Fig. 31 makes

it evident that if the line A B represent the plane surface of the blackboard and if the eye be placed at O the equal increments of 10° on the quadrant become a series of increasing increments upon the surface of the board. The numbers at the right (Fig. 31) show just how many centimeters the radius of each successive circle should be provided the distance of the eye from the board be taken at 20 centimeters.

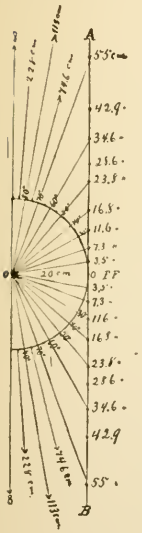


Fig. 31.

Fig. 31. For description see **L=2.**

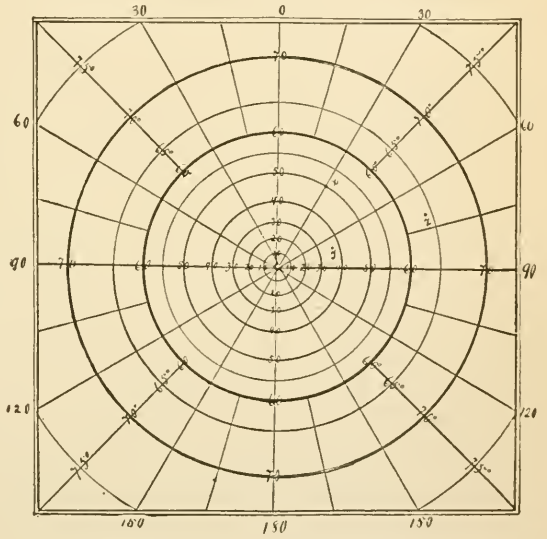


Fig. 32.

Fig. 32. Showing method of ruling a blackboard for use in perimetry. The radii of the circles are given at the line A B in Fig. 31.

After drawing the circles, draw meridians which divide each quadrant into three to nine subdivisions. The completed blackboard chart will have the appearance and proportions shown in Fig. 32. The circles and

meridians should be traced permanently in slate-colored enamel upon the surface of the blackboard. Any marks made upon the board with chalk may then be erased without disturbing the perimeter circles.

Make test objects in this manner. To a soft pine disc 3 or 4 cm. in diameter and 1 cm. thick fix a 20 cm. handle of hard wood. The whole should be given a dead black surface, India ink is good for this purpose. Upon the disc one may fix with a pin the test object : a circle or a square or other form in white, yellow, green, blue or red.

Each blackboard chart must be provided with a *rest* or contrivance to insure that the subject's eye is 20 cm. from the surface of the board. Whether this takes the form of a rod of wood extending out from the board and so adjusted that when the subject rests the most prominent infra-orbital region upon its end, *the cornea will be 20 cm. from the center of the chart;* or whether it takes some other form that insures the same result is of little consequence.

3. *Experiments and Observations.*

In all the observations which are subsequently indicated, it is taken for granted that the visual axis is perpendicular to the surface of the chart, that the center of the chart is the point of fixation, and that the accommodation is kept uniform, i. e., the eye is either uniformly focused on the pole of the blackboard perimeter or uniformly relaxed; further that the eye not under observation be closed or closely shaded.

(1) Examine the upper median quadrant by sweeping a white circle or square around arc. 60°, keeping the test object as near the surface of the chart as possible. If the subject does not see it at all, try latitude 50°. Having located the circle which seems to be near the boun-

dary, locate upon each meridian a point which indicates the limit of indirect vision in that direction. Join with a continuous line the points located, thus inclosing an area of indirect vision.

(2) Test the lower median quadrant in the same way. Is the total area covered by indirect vision in this quadrant greater or less in extent than that in the upper quadrant?

(3) Test the upper-lateral quadrant and then the lower-lateral quadrant. Are these two quadrants practically equal?

Is there any ready explanation why the outer two quadrants should contain such an excess of area over the inner two quadrants?

(4) *To record the perimeter outline.*

For this purpose one should have printed charts like the one given in Fig. 33. Note that here the circles are equidistant. They represent concentric arcs of a quadrant with 10° of the circle between each two, while the circle upon the blackboard-chart represent a radial projection of these arcs upon a plane tangent to the sphere at the point of fixation.

In transcribing the perimeter upon the record chart one has only to locate the twelve or more points located upon the observation chart and join these points into a continuous perimeter.

Point x, Fig. 30 for example, would naturally fall at x′ Fig. 31; point y corresponds to y′; Z to Z′ whose reading is: "Upper-lateral quadrant arc 64°, 70° from vertical.

(5) In the above experiment we have determined the perimeter for *light* sensation only; the subject being conscious simply of a light or white spot on a dark ground but not certain whether the spot is circular or

square. Determine now the *form* perimeter, i. e., the limits of the field within which a circle can be definitely differentiated from a square or triangle.

Chart the *form-perimeter*, i. e., transcribe the perimeter upon the record chart. Is it similar in general

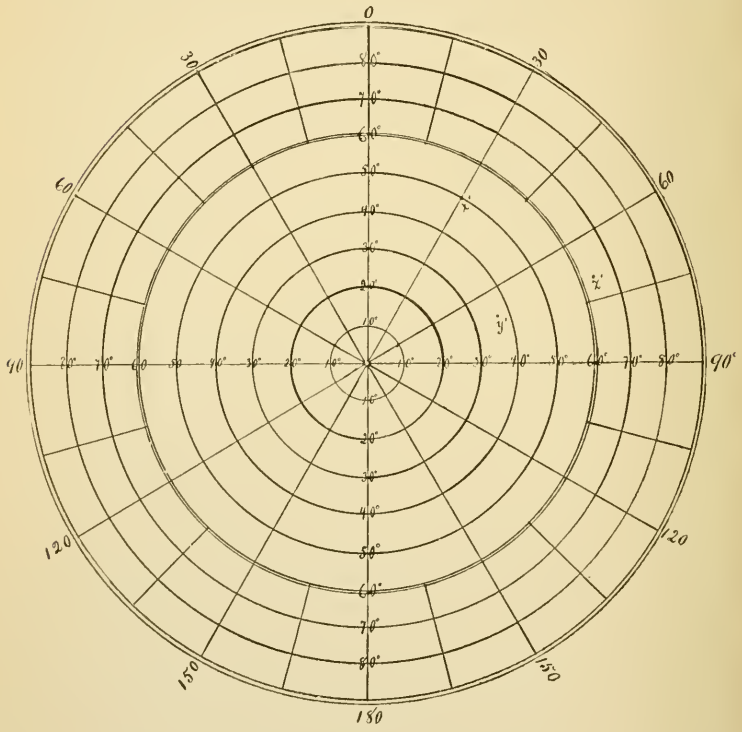


Fig. 33.

Fig. 33. Perimeter chart for recording the limits of indirect vision for light, for color, and for form.

form to the *light perimeter?* Is it much smaller in area? Determine and chart various *color-perimeters:* (a) yellow; (b) red; (c) green and (d) blue.

Have the color-perimeters the same general form as the light-perimeter? If not, describe any noticeable variations. Which of the color-perimeters incloses the greatest area? Enumerate them in order of area. Is this the order which one would expect? Give grounds for position.

(7) Take corresponding perimeter for the other eye. To use the same blackboard it will be necessary to turn it the other edge up. In what general respect do the perimeters of the right eye differ from those of the left?

(8) With the help of the light or form-perimeters of the right and left eyes, *determine the field of binocular vision.* Is this the field of binocular *direct* vision or binocular *indirect* vision?

LI. Determination of normal vision. a. The acuteness of direct vision. b. The range of accommodation. c. The amplitude of convergence.

a. The acuteness of direct vision.

1. *Appliances*—Charts printed with Snellen's test type; astigmatic chart; test lenses of following strength: +.50 D., +.75 D., + 1.00 D., + 2.00 D., + 3.00 D., —.50 D., —.75 D., — 1.00 D., — 2 00 D., — 3.00 D., + 1.00 D. cyl., + 2.00 D. cyl., — 1.00 D. cyl. — 2. D. cyl.; simple test frames, and shade; a photometer; Holmgren's worsteds.

2. *Preparation.*—Preparatory to testing normal vision it is necessary to make a few general statements regarding: (1) *The numeration of lenses.*

The refractive power of a lens is the reciprocal of its focal distance. The refractive power of a lens whose focal distance is 1 m. is, for example, only one-half as great as that of a lens whose focal distance is 0.5 m. Monoyer introduced the term dioptre as a unit in measuring lenses. One dioptre—(1 D.)—represents the refractive power of a lens whose focal distance is 1 m.; 2 D. corresponds to ½ m.; 3 D. to ⅓ m.; 4 D. to ¼ m., etc. 0.5 D. represents the refractive power of a lens of 2 m. focal distance; 0.25 D. of 4 m. focal distance, and 0.125 D. of 8 m. focal distance. If the lenses are convex (bi-convex) a plus sign is prefixed to the number, i. e., + 5 D., means a *bi-convex* lens of 5 dioptres refractive power, or $\frac{1}{5}$ m. focal distance. While — 5 D. means a *bi concave* lens of $\frac{1}{5}$ m. negative focal distance.

The use of cylindrical lenses is frequently necessary. A cylindrical lens is a section of a cylinder parallel to its axis. Cylindrical lenses may be convex or concave. A convex cylindrical lens capable of bringing rays to a linear focus at a distance of one half meter would be designated as follows: + 2 D. cyl.

(2) *Test types and visual angle.*

The *visual angle* is that included between lines joining the extremities of an object and the nodal point, or the angle subtended by an object, at the nodal point. In Fig. 29 the object at d subtends the angle v, while the object at D though much larger subtends the same angle v. Now it has been determined by Snellen that the normal eye distinguishes letters subtended by an angle of 5 minutes. If we let d=distance of object from nodal point, n=distance of image from nodal point, i length of image and o of object, then:

(1) $i : o :: n : d$;

(2) $o = \frac{i}{n} d$;

(3) but $\frac{i}{n} = \frac{\sin v}{\cos v} = \tan. v$;

(4) $\therefore o = d \tan. v$.

The tangent of $5' = 0.001454$; assume $d = 1$ m (1000 mm.); what is the height of the smallest letter discernible to the average normal eye at that distance?

At 1 m. height of letter, $o = 0.001454 \times 1000 = 1.45$ mm.

Determine the height of the letters for each of the following distances respectively: 60 m., 30 m., 20 m., 15 m., 12 m., 9 m., 6 m., 4.5 m., 3 m., 2.5 m., 2 m., 1.5 m., 1 m., 0.75 m., 0.50 m.

What is the size of the image in all these cases? A cultivation of the visual power of the eye may readily in the emmetropic eye bring up its definition

to ¼ above the average or so that the minimum visual angle for acute vision equals 4′. What is the size of the image when it subtends an angle of 4′? The test letters are made with the width of the strokes ⅕ the height of the letter. What is the size of the retinal image of one of the strokes?*

3. *Experiments and Observations.*

(1) *To test the form sense.*—In all of the tests here described it is understood unless otherwise stated that the subject sit directly facing the chart which should be six meters distant, and well illuminated.

(1) Let the subject put on the test frames with the left eye shaded, and direct the right eye to the letters of the line marked 6 m. These letters in their vertical dimension subtend an angle of 5′. The average normal eye will be able to recognize easily every letter in the line. Should there be any hesitation in the differentiation of C from G, of P from D or F, of K from X, etc., make a note of it; its significance will be apparent later.

Now in recording the acuteness of vision one compares the minimum angle of distinct vision in the subject under observation with the normal. If the subject reads readily at 6 m. the type that is normal for 6 m., he is credited with normal vision or with a minimum visual angle normal or unity. This is expressed in the following manner: Let V equal visual acuteness; d, the distance from chart; D, the distance at which the type should be read: $V=\frac{d}{D}$. In the above case $V=\frac{6}{6}$ or 1, i. e., normal vision.

(2) Suppose that the subject cannot read the 6 m.

* The size of the cones of the macular region varies from 0.0033 to 0.0036 mm. in diameter.

line readily, let him try the line above. If he reads that readily his visual acuteness would be: $V = \frac{d}{D} = \frac{6}{9}$; two-thirds normal. It is usual, however, not to reduce the fraction but to use 6 for the numerator always.

(3) How shall one express visual acuteness for an individual who reads at 6 m. what he should read at 21 m.? At 24 m? At 30 m.? At 4.5 m.? At 3 m.?

(4) How many members of the class have a visual acuteness greater than unity? May a visual acuteness above the normal be attributed in any degree to cultivation of the vision, or is it to be interpreted solely as a natural endowment?

(5) Make upon a white card with india ink a series of vertical lines 1 cm. apart, beginning with a line of 1 mm. breadth, and decreasing gradually to a hair line; place the card upon a blackboard 6 m. distant; let a subject with high visual acuteness say how many of these lines he can see.

With dividers and rule measure the breadth of the finest of the lines seen. What is the visual angle of that breadth? What is the breadth of the retinal image of the line? Can the subject see the same number of lines when they are horizontal? If not, how may the fact be accounted for?

(6) If it be found that the subject cannot see clearly the largest letters upon the test chart let him move to a shorter distance.

Suppose that he sees clearly the 30 m. type at 2 meters, what is the value of V? How far would he be able to read the 6 m. type? At what distance would he probably have to hold a book whose type has a height of 1.8 mm.?

(7) (*a*) Let a subject take the seat, 6 m. distant

from the chart. Hold before his eye a +0.75 D. lens, it will probably make indistinct and blurred distant objects which were, without the lens, clear. If such be the case it is likely that refraction of the eye is normal and for our purpose it may be recorded as an *emmetropic eye.*

(*b*) If, however, the vision remains perfectly clear for distant objects, with the +0.75 D. or the +1 D. lens before the eye it is evident that the refraction of the eye is not normal.

(*c*) Suppose, on the other hand, that distant objects cannot be clearly seen with the unaided eye; but, with the help of concave lenses, clearly seen, it is evident again that the refraction of the eye is abnormal.

(8) In case (7 *c*), where were the parallel rays focused when the concave lens was used? Where were the parallel rays focused in the unaided eye? Would it be possible for the condition to be corrected by an exercise of the accommodation? If the punctum remotum is 2 m., and if the refractive indices and curvatures of the refracting surfaces are all normal, in what way must the eye differ from the normal eye? This condition is called nearsightedness or *myopia.*

(9) In case (7 *b*), if a subject can read all of the letters expected of the normal eye one credits him with $V=\frac{6}{6}$; but, the eye may have accomplished the result at the expense of more or less effort.

If the eye have a *punctum remotum* beyond infinity; *i. e.*, if the rays of light from a distant object are not yet converged to a focus by the time they reach the retina *in the resting eye* it will require a certain effort of accommodation to produce a clear

image. Such is the condition in the *farsighted* person, the condition is called *hyperopia*. The term *farsightedness* does not mean that the subject can see farther than the average individual but that he can see far more easily than near. If a subject with $V=\frac{6}{6}$ can see as clearly or more clearly when the $+0.75$ D. lens is in front of the eye there is no reasonable doubt that hyperopia in some form is present.

(10) Let the subject direct the line of vision toward the *center* of the chart for testing astigmatism. It is probable that not all of the radiating lines will appear equally clear cut and black, for most persons have a small degree of astigmatism. If the lines are unequally clear, where are the clearest ones located? Do they describe a diameter across the circle? If so, describe the location of the clear diameter, 0°—180° being the horizontal diameter, and 90°—90° the vertical one.

(11) (*a*) If the subject has normal vision with no astigmatism or normal vision despite a slight astigmatism, he may be given a better conception of just what a moderate degree of astigmatism is by putting a $\pm$ 1 D. cyl. lens before his eye; or a rather high degree of simple astigmatism by trying a $\pm$ 2 D. cyl. or $\pm$ 3 D. cyl.

(*b*) How may the subject be made artificially hyperopic?

(*c*) How, artificially myopic?

II. *To test the light sense.*

With the photometer test the subject's power to determine the difference in the illumination of the two discs of the instrument.

III. *To test the color sense.*

Let the subject take the three test colors: light green, purple and red, and choose from the mass of worsteds the colors which he considers similar ones, placing the chosen color in the class to which it belongs. It is not difficult to determine whether or not the subject has a normal color sense. If, for example, he is *red blind* he will not see the red in the purple, or related colors, but will classify these with the blues, while the reds will be confused with the greens.

b. The range of accommodation.— The amount of refractive change induced by the eye in adjusting for its punctum proximum after it has been at rest, i. e., after it has been adjusted for its punctum remotum, is termed the range of accommodation. In a previous chapter the *punctum proximum* and *punctum remotum* were determined. It was reserved for this place to express the position of these limits of accommodation in terms of dioptres, and thus most readily determine and definitely express the *range* in simple dioptres. The relation of this to what has just preceded will be evident.

Let R represent the distance of the punctum remotum from the eye, then the refraction at rest or the static refraction r equals the reciprocal of the distance:

$$(1)\ r = \frac{1}{R}.$$

Let P be the distance of the punctum proximum from the eye, then the maximum refraction of the eye, p equals the reciprocal of the distance:

$$(2)\ p = \frac{1}{P}.$$

When $R = \infty$, $\frac{1}{R} = 0$, i. e., static refraction equal zero.

When $P = \frac{1}{8}$ meter, $\frac{1}{P} = 8$.

Let A equal the range of accommodation; Donders expressed the range of accommodation thus:

$$(3)\ \frac{1}{A} = \frac{1}{P} - \frac{1}{R}.$$

$$(4)\ A = \frac{PR}{R - P}.$$

Take an example: Let the punctum remotum be 50 cm. (½ m.) from the eye, the punctum proximum 10 cm. ($\frac{1}{10}$ m.); substitute the distances expressed in meters in formula (4) and one obtains A = $\frac{1}{8}$ m. The range of accommodation, i. e., the accommodative power of the eye is equal to a lens of $\frac{1}{8}$ m. focal distance. But a lens of $\frac{1}{8}$ m. focal distance is an 8 dioptre lens. A much simpler way of arriving at this result is to use:

r ($= \frac{1}{R}$) and p ($= \frac{1}{P}$). If we let a $= \frac{1}{A}$, then we may write:

$$(5)\ a = p - r.$$

To apply this formula to the above example we have a = 10 D. — 2 D. = 8 D.

1. Experiments and Observations.

(1) Determine the range of accommodation for each member of the class.

(*a*) Determine punctum remotum and punctum proximum.

(*b*) Record these quantities in meters.

(*c*) Substitute these values in formula (5) expressing the distances in the corresponding dioptres, i. e., using the reciprocals of the distances.

(2) *Range of accommodation in myopia.*

(*a*) Is r positive or negative in myopia?

(*b*) Is a always less than p, or may it sometimes be greater?

(*c*) What is the average range of accommodation of the myopes of the class?

(3) *Range of accommodation for emmetropia.*

(*a*) What is the value of R in emmetropia?

(*b*) What is the value of r in emmetropia?

(*c*) What is the relative value of a and p in this class of cases?

(*d*) What proportion of emmetropes in the class?

(*e*) Have they all the same range of accommodation?

(*f*) Can any probable cause be assigned for any variations which may be found?

(*g*) How does the average range for emmetropes compare with the average range for myopes?

(4) *Range of accommodation for hyperopia.*

(*a*) If the *punctum remotum* is "beyond infinity" (!) that is equivalent to saying that the eye at rest does not focus parallel lines (from infinity) upon the retina, but the lines must be more than parallel, i. e., from *beyond* infinity; or, better, *convergent;* but if they are convergent they would meet behind the cornea. The p. r. for hyperopes is then *negative* in direction and is equal to the distance, behind the cornea, at which the convergent lines would meet if prolonged. It follows that $\frac{1}{R}$ is in the case of hyperopes negative. Our formula (3) would then take the form:

$$(3') \quad \frac{1}{A} = \frac{1}{P} - \left(-\frac{1}{R}\right) = \frac{1}{P} + \frac{1}{R}.$$

Therefore, formula (5) becomes (5′) $a = p + r$. Now, in determining r one may use a convex lens of such a strength as to give the rays the requisite convergence. The value of the lens in dioptres is, of course, the value of r. In the hyperope a is always greater than p. As the determination of the *punctum remotum* of the hyperopic eye is a matter

for the clinician to deal with, we will omit its determination here.

(*b*) If a member of the class wears glasses having the following formula for the right eye, +2D, and if his punctum proximum is 12.5 cm. distant from the cornea, what is his range of accommodation?

(*c*) What is the range of accommodation of those hyperopes in the class whose punctum remotum may be determined from the lenses which they use?

(*d*) May variations in range be accounted for?

(*e*) Is the average range greater or less than that for myopes? For emmetropes?

(5) Tabulate the values of p and of r for the class, first, with respect to age, arranging in the first column all of the cases which range between eighteen and twenty years, in the second column twenty-one to twenty-three, and so on. Determine the average for p and for r from each age column.

(*a*) Does age within the limits of your table affect the punctum proximum? If so, how?

(*b*) Does age affect the punctum remotum as shown by your table?

(*c*) If the volume of data justifies it, make a chart showing the effect of age upon the range of accommodation. Use the age units for divisions of the axis of abscissas, and dioptre units of p and r for the divisions of the axis of ordinates.

c. The amplitude of convergence.—The fact of the convergence of the visual axes of the two eyes in binocular vision has been demonstrated in a previous lesson. We come now to the measurement of this function.

To measure convergence.—To get a clear conception of the situation, let us call the line which joins the centers of rotation of the eyes the *base line*. A plane perpen-

dicular to the middle of the base line may be called the *median plane.* Any point in this plane which is fixed by the two eyes in binocular vision may be called the *point of binocular fixation.* The line joining this point to the middle of the base line would lie in the median plane, and would be called the *median line.*

If the point of fixation be at a great distance (infinity) the lines of fixation of the two eyes would be parallel to the median line. In this case there would be no *convergence.* If, however, the point of fixation be near there will be a convergence of the two lines of fixation toward that point. The amount of convergence is greater the nearer the point, and is called the *angle of convergence.* The angle of convergence is then the angle between the line of fixation at infinity and the line of fixation at the given distance less than infinity, the given distance being measured on the median line, beginning at the base line.

The geometric situation is indicated in the accompanying figure (Fig. 34). Let C represent the center of rotation of the left eye, M the middle of the *base line* and the origin of the median line; CP the line of fixation of an object at infinity; MM′ the median line; the line CM is one-half the base line; represent the distance CM by b. The angle D′CP is the angle of convergence when D′ is the point of binocular fixation. As to the exact measure of the angle, it is evident from the figure that the line MD′, which we may represent by d, is the cotangent of the angle of convergence (ang. c).

The unit of measurement for the angle of convergence is the *meter angle* (Ma) of Nagel. The meter angle is the angle of convergence when the point of binocular fixation is 1 m. distant (d=1,000 mm). Ma equals the angle whose cotangent is $\frac{d}{b}$ (cot Ma=$\frac{d}{b}$). The aver-

age base line being 64 mm., the average Ma may be thus expressed: Cot $Ma=\frac{1.000}{32}$; $Ma=1^\circ\ 50'$. It is not customary to use in practice the absolute values for the angles, but a convenient series of approximate values suggested by Nagel.

If d=500 mm. (½ m.), ang. c=2 Ma; if d=⅓ m.,

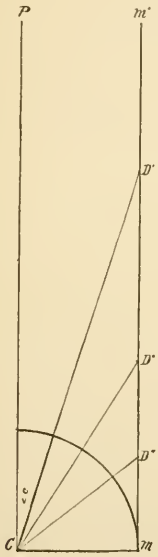


Fig. 34.

Fig. 34. For description see **LI=c.**

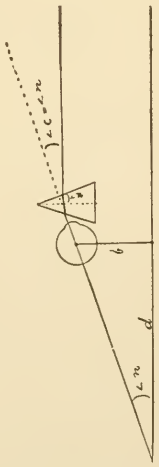


Fig. 35.

Fig. 35. For description see **LI-c=(5).**

ang. c=3 Ma. If d=¼ m., the accommodation = 4 D and angle of convergence = 4 Ma.

Besides the convenience of this system, it indicates at once the direct relation between accommodation and convergence.

The amplitude of convergence is the total number of

meter-angles of convergence which the individual can call into play. It is the difference between the punctum proximum of convergence [p^c] and the punctum remotum of convergence [r^c] expressed in meter angles; which are really the reciprocals of the distances. This may be thus expressed:

(1) $\frac{1}{A^c}=\frac{1}{P^c}-\frac{1}{R^c}$ in distances, or;

(2) $a^c=p^c-r^c$ in meter angles.

Experiments and Observations.—Let each member of the class be in turn the subject of examination.

(1) Determine the *pupillary distance*, i. e., the distance from the center of one pupil to the center of the other when the eyes are fixed on a distant object. One-half of this is approximately equal to b, and in the experiments which follow may be used as such.

(2) Take a board 1 m. in length and 10 cm. in width. Along the middle of one side draw a line which may represent the median line; graduate the line in decimeters; the proximal ½ m. may be graduated in centimeters. At each centimeter or decimeter bore a small hole into which a post may be set. Make two posts about 5 cm. or 10 cm. in height; into the top of one set a needle, split the top of the other so that it will hold a card printed with fine type (not to exceed 1 mm. in height, finer if possible). Support the board so that it shall be in a horizontal plane and 5 cm. or 10 cm. below the eyes.

(3) *To determine the punctum proximum of convergence*: (*a*) Let the subject sit so that the line on the board shall be in the median plane and parallel to the median line; let him look at the needle when the post is set at 1 m. Supposing that his punctum remotum is at infinity, what is the ang. c.?

(*b*) Let the subject look in turn at the needle when the post is set at 50 cm.; at 40 cm.; at 30 cm.; at 25 cm.; at 20 cm.; what is the ang. c in each case, expressed in meter angles?

(*c*) From this point if the needle appears perfectly clearly defined move the post up toward the eyes 1 cm. at a time as long as the vision is binocular and the image single.

As soon as the image is double one may be certain that the eyes are no longer able to converge sufficiently to bring the images upon corresponding points of the retina and that the punctum proximum of convergence (p^c) has been passed. Find the nearest point at which the image is single—the nearest point at which the fine printing on the card is perfectly clear; this is the punctum proximum of convergence (p^c).

(*d*) Determine the punctum proximum of convergence for each individual in the class.

(4) *To determine the punctum remotum of convergence* (r^c). If the eyes can be directed parallel but cannot diverge, the punctum remotum may be expressed as follows: $r^c = \frac{1}{R} = \frac{1}{\infty} = 0$. Landoldt says, however, that "the majority of normal eyes can diverge more or less," i. e., there is a *negative convergence* ($-r^c$).

The formula—(2) . . . $a^c = p^c - r^c$ becomes

$$a^c = p^c - (-r^c); \text{ or}$$

$$(2') \ldots a^c = p^c + r^c$$

Let it be noted that in this case the value of r^c cannot be determined by carrying the object to a greater distance, but recourse must be had to *abducting prisms*, i. e., prisms whose apices are turned away from the median line. The negative convergence may

be determined by finding "the strongest prisms which a person can overcome"; while seeing a distant object, without double vision. The deviation of a prism may be taken as half the angle of the prism; a No. 6 prism, produces a deviation of 3°. If only one prism be used the 3° is divided equally between the two eyes. Let it be understood that two prisms of equal angle be used.

(5) *To compute the ang. c in meter-angles for any prism and any length of base-line.*

Let n equal the angle of deviation, i. e., one-half the number of the prism. Let b equal one-half the base-line. Let d equal the distance of the punctum remotum, to be computed. Then,

(1) b : d : : sin n : cos n (see Fig. 35).

$$(2) \ldots . d = b. \frac{\cos n}{\sin n} = b \cot n.$$

But the punctum remotum of convergence (r^c) expressed in meter-angles, is found by dividing 1m. by d, therefore

$$(3) \ldots . r^c = \frac{1000}{b \cot n}$$

If a person whose base-line is 64 mm. is able by divergence to overcome a pair of No. 6 prisms his punctum remotum of convergence would be negative and equal to 1.63 Ma. Determine the punctum remotum of convergence for each individual in the class.

(6) Determine the amplitude of convergence for each member of the class using the formula; $a^c = p^c - r^c$. Tabulate the results.

(7) Compare this table with the one in which the range of accommodation is recorded. Is there any parallelism in the variations of accommodation and convergence? Does age seem to have any appreciable influence upon the amplitude of convergence?

OPHTHALMOSCOPY AND SKIASCOPY.

By ALFRED M. HALL, A. M., M. D.

LII. Normal ophthalmoscopy, direct method.

Gould defines ophthalmoscopy as, "the examination of the interior of the eye by means of the ophthalmoscope." Normal ophthalmoscopy is the examination, by means of the same instrument, of the normal eye or a model of the normal eye.

1. *Appliances.*—An ophthalmoscope, with concave mirror; dark room; lamp; and Thorington's skiascopic eye or an equivalent.
2. *Preparation.*—Arrange the model and the lamp so that they will be in the horizontal plane with the observer's eye. Place the skiascopic eye directly in front of the observer's eye, and the lamp a little to one side of the model.
3. *Operation.*—Let the observer hold the ophthalmoscope with the right hand, mirror forward, close to the eye, directing the vision through the hole in the instrument. Throw the light, reflected by the mirror, into the skiascopic eye. Find the red reflection of the fundus, then gradually lessen the distance between the observer's eye

and the model to about 2 or 3 cm. The skiascopic eye will then be illuminated and the fundus with its structures will be clearly defined.

4. *Observations.*

a. Adjust the model to represent the emmetropic eye.

(1) Determine, with the ophthalmoscope, the color of the fundus. Enumerate the structures seen.

(2) Describe the *papilla*, or entrance of the optic nerve. Is the papilla in the visual axis or to one side of it? Describe its position with respect to the visual axis of the eye and determine the most advantageous position of observer, model and instrument to get a direct view of the papilla in the right eye; in the left eye.

(3) Describe the location of the *arteria* and *vena centralis retinæ* with reference to the papilla.

(4) The ring formed by the border of the papilla is sometimes called the *scleral ring* or the *choroidal ring.* Can this ring be distinctly seen?

(5) The *macula lutea* and the *fovea centralis* are the most sensitive portions of the retina and are in a direct line with the visual axis of the eye.

What is the most advantageous position of model, observer and instrument in order to get a direct il lumination of this part of the fundus? Describe the appearance of the structures in question.

(6) Describe the retinal blood vessels minutely; drawing a map of their distribution.

b. The observation of the retina in the hyperopic eye.

Adjust the model for three dioptrics of hyperopia.

(7) Are the retinal blood vessels distinct when the above described method of observation is used?

(8) Place in the rack, before the model eye, the follow-

ing lenses, with each one testing for a distinct retinal image:

*$\pm$ 1 D., $\pm$ 2 D., $\pm$ 3 D., and $\pm$ 4 D.

With which one of the lenses is the clearest image obtained? Are all of the images of equal size? Explain, giving a figure.*

(9) In hyperopia do the rays focus in front of, on, or behind the retina? What direction do the rays take after leaving the hyperopic eye from the illuminated retina? Are they parallel, divergent or convergent?

c. Observation of the retina in a myopic eye.

Adjust the model for myopia, e. g., three dioptrics.

(10) Are the retinal blood vessels distinct?

(11) What direction do the rays from the retina take on emerging from the myopic eye, divergent, convergent, or parallel?

(12) In which of these three cases would the normal eye be able to get a clear image of the retinal structures?

(13) In which case would a correcting lens be necessary? Should one use a convex or a concave lens; and why?

*In all work with the ophthalmoscope or retinoscope it is understood that the observer's eye is emmetropic, either by nature or by correction, and that his accommodation is suspended. One may get a clear view of the retina without fulfilling these conditions, but one cannot draw reliable optical conclusions.

LIII. Normal ophthalmoscopy, indirect method.

1. *Appliances.*—The same as in exercise LII, with the addition of a lens of + 12 D. to + 20 D.
2. *Operation.*—With the model or eye to be observed, the light and the observer arranged as in exercise LII, direct the light reflected by the mirror into the observed eye and find the red reflection of the fundus of the eye. Hold the lens between the thumb and index finger and place it directly between the mirror and the eye under examination, and at a distance from the latter of 6–8 cm. Be careful that the center of the lens corresponds to the center of the pupil and that the plane of the lens is perpendicular to the line of vision.
3. *Observations.*
   a. *Observation of the emmetropic eye.*
      (1) The rays of light emerging from the observed eye are focused by the convex lens, which the observer holds, and form an aerial image of the retina. If a + 12 D. lens be used, and if its optical center be held 8 cm. from the anterior surface of the cornea, how far from the cornea will the aerial image be formed?
      (2) Trace in the image all of the structures enumerated in the direct method. Is the image erect or inverted? Is the field larger or smaller than one sees in the direct method? Are the structures magnified or the reverse? Account for all phenomena, representing the optics of the case with a figure.
      (3) Does a change in the distance between the cornea of the model or eye and the lens which the observer

holds alter the size of the image? Account for observation.

b. Observation of the hyperopic eye.

Adjust the model for 3 D. of hyperopia.

(4) Does an increase of the distance of the lens from the cornea cause the image of the papilla to be altered in size? Account for all phenomena.

c. Observation of the myopic eye.

Adjust the model to represent 3 D. of myopia.

(5) Does the increase of the distance of the lens from the eye cause the image of the papilla to become altered in size or reversed in position? Account for all phenomena.

(6) If the position of the + 12 D. lens which the observer holds remain the same—8 cm. from cornea—will there be any variation in the distance from the cornea of the retinal image for the hyperopic eye and myopic eye?

Will the distance for the hyperopic eye be greater or less than for the emmetropic eye? Why? Will the distance for the myopic eye be greater or less than for the emmetropic eye? Why?

d. Observation of the human eye.

At this point in the student's work, let him practice the direct and indirect method of ophthalmoscopy upon his comrades, after two or three days of practice he may pass to the following exercise.

LIV. Skiascopy.

Gould defines skiascopy as "a method of estimating the refraction of the eye by observation, through the ophthalmoscopic mirror, of the movements of the retinal images and *shadows*." Synonyms: Fundus reflex test; umbrascopy; pupiloscopy; koroscopy; keratoscopy; retinoscopy, etc.

1. *Appliances.*—A simple retinoscope or an ophthalmoscope with a plane mirror; Thorington's skiascopic eye or an equivalent; dark room; lamp; etc.
2. *Operation.*—The observed eye and lamp are to have the same relative position as in ophthalmoscopy. Let the observer sit directly in front with the eye in the same horizontal plane with the lamp and observed eye, and somewhat more than 1 m. distant from the observed eye. Throw the light reflected by the mirror into the observed eye; rotate the mirror slowly and a shadow will be seen in the pupil of the observed eye.
3. *Observations.*
   a. *Observation of the emmetropic eye.* Adjust the model to represent emmetropia.
      (1) Does the shadow move in the same direction as the mirror rotates or in the opposite direction, i. e., does the shadow move "*with the mirror*" or "*opposite?*"
      (2) Is the movement of the shadow *quick* or *slow.*
   b. *Observation of the myopic eye.*
      (1) Adjust the model to represent less than 1 D. of myopia.
      (3) Note that the shadow movement is with the

direction of the mirror rotation and that it is relatively quick.

(II) Adjust the model to represent a myopia of more than 1 D.

(4) Note that the shadow movement is opposite the direction of the mirror rotation and that it is *quick* when the myopia is of low degree, *slow* when of high degree.

(5) Observe alternately the three conditions indicated above until their differences are so familiar that any one of the conditions may be readily and unerringly detected by the observer when they are arranged for him by the instructor.

c. Observation of the hyperopic eye.

Adjust the model to represent any degree of hyperopia.

(6) Note that for a low degree of hyperopia the shadow movement is *with* the mirror rotation and *quick.*

(7) Note that for higher degrees of the condition the shadow movement is *with* the mirror and *slow.*

(8) How may one differentiate a high degree of myopia from a high degree of hyperopia?

(9) Is there any difference in the size, shape, distance or position of the shadows in these two conditions?

d. Observation of the human eye.

Let the student practice upon his comrades.

NOTE: Observation of the astigmatic eye is intentionally omitted here. It belongs more espcially to the clinical phase of the subject.

PHYSIOLOGICAL HÆMATOLOGY.

G. PHYSIOLOGICAL HÆMATOLOGY.

By W. K. Jaques, Ph. M., M. D.

INTRODUCTORY.

The scientific world is constantly giving her discoveries to the medical profession to be utilized in diagnosing disease and in providing means to relieve suffering. Each fact thus obtained is a step nearer to the goal of positive medicine and removes us farther from the past with its unsatisfactory theories and dogmas.

Blood, the most difficult tissue to study, has at last begun to give up its secrets to the patient workers in physiological and pathological laboratories. Although the facts are few compared with the great labor it has taken to obtain them, they are of such practical value that no practitioner can afford to be without them.

The discovery that toxins and antitoxins were contained in the blood serum made possible the production of diphtheritic antitoxin and gives us the serum diagnosis of typhoid fever, beside opening a wide field of possibilities for the future.

The finding of the plasmodia of malaria is often of the greatest value in clearing up an obscure diagnosis. When methods shall have been devised which will make their detection less difficult, the discovery of the presence of bacteria in the blood and the identification of the same will be of great clinical importance.

To understand the appearance of pathological blood, a knowledge of normal or physiological hæmatology is essential. It is the object of the following pages to assist the student in obtaining this knowledge and in laying the foundation for the study of pathological hæmatology.

A knowledge of the microscope and its technique is essential and the work of the student should be so arranged as to include considerable practice with that instrument before entering upon a study of that subject.

If the practitioner has a fair knowledge of pathology, histology and bacteriology, with the help of the following suggestions he may take up with profit the subject of hæmatology.

In class work the blood may be obtained from students. The pain is minimized if the blood is properly obtained, and practice on themselves will impress this fact upon the students. The general practitioner can get material from his patients.

The technique of hæmatology can only be acquired by practice. The student will secure this more readily than the practitioner because his attention will not be distracted by diagnostic possibilities. It is well for the practitioner to go over the whole ground several times for the sole purpose of mastering every detail. Unless the technical part of the work is correctly and easily done, the specimens will be unsatisfactory, the results will be untrustworthy and the knowledge of the subject imperfect.

The methods here employed are those of the best students of hæmatology with modifications from the experience of the author. Although the best to-day, to morrow they may be remembered only as the stepping stones to more perfect work. Many truths are yet undiscovered in this wonderful river of life—the blood—and the gratitude of a race will be due him who reveals them.

LV. Examination of fresh blood.

1. *Appliances.*—Microscope; one twelfth inch oil-immersion lens; 22 mm. cover glasses; slides; saddler's needle and holder; clean piece of old muslin one-half meter square; paper and pencil.
2. *Preparation.*—Clean cover glasses and slides as follows: Immerse in 60% acetic acid, then wash in soap and water and place in dilute alcohol; just before using, wipe dry and place under a bell-jar; the needle should be so placed in the holder that it protrudes one-fourth to one-third inch.

   A convenient needle-holder, the exact size of which is shown in Fig. 36, may be obtained from a dental supply house.



Fig. 36.

   A medium saddler's needle may be obtained from a harness shop. If too long, it can be broken and the point used. These needles have three cutting edges so that blood flows easily from a puncture made by one.
3. *Operation.*—Wipe the lobe of the ear with a damp cloth; then briskly with a dry cloth; seize the lobe with the left finger and thumb quite tightly; thrust the needle into the ear with a quick stroke. Wipe away the first drop; then when the second drop has become a little more than one-eighth of an inch across its base, bring the center of the cover glass under the drop and touch the lower part without touch-

ing the ear as shown in Fig. 46. Quickly place the cover glass, blood-side down on a clean slide and examine.

4. *Precautions.*—Cover glasses must be clean, dry and free from dust. The blood must be collected quickly or it will form rouleaux. A warm stage prolongs the normal appearance of the blood. Placing the microscope in the incubator at body temperature for half an hour before using will keep the slide warm for some time. In adjusting the needle for puncture the condition of the patient should be considered. A full blooded patient will require a smaller puncture than an anæmic one.

5. *Observations.*—Note that the red corpuscles are round in shape. As the plasma dries, it causes currents; as the corpuscles float in these they strike each other, dent, elongate and act like bags of jelly, returning to their round shape when free.

a. Red corpuscles.

(1) Note biconcavity; what causes it?

(2) Are there variations in the size of the red cells?

(3) What is crenation? Note when it begins.

(4) Do you see two motions of red corpuscles? Describe any motion seen.

(5) Do you see small motile bodies in the plasma?

b. White corpuscles.

(6) How do white corpuscles differ from red?

(7) Do they float as easily in the blood current?

(8) How do they compare in size with red corpuscles?

(9) Why are white corpuscles smaller in fresh blood than in dried specimens?

(10) What movements do you see?

(11) Do you see any variation in size?

(12) In which kind do you see the amœboid movements?

(13) Do you see some white corpuscles with large granules?

(14) What is the approximate ratio of the white cells to the red?

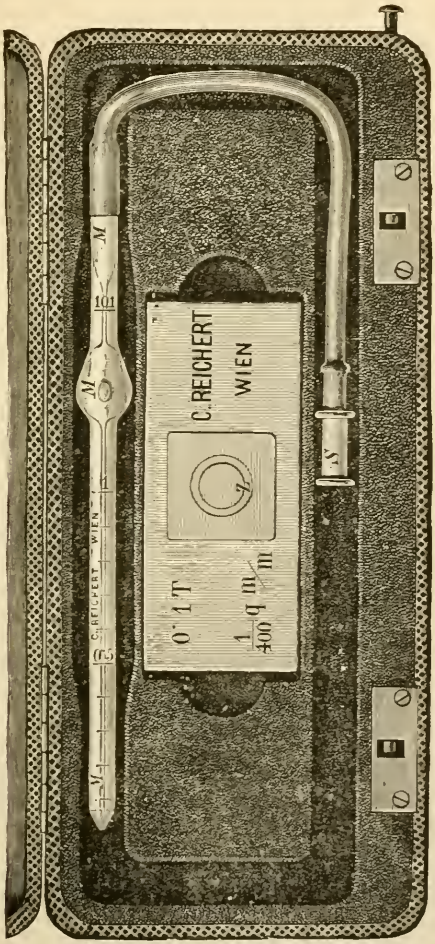


FIG. 38a. Thoma-Zeiss blood-corpuscle counter.

LVI. Counting red corpuscles.

1. *Appliances.*—Microscope with one-seventh inch objective, and a mechanical stage; needle and holder; Thoma-Zeiss counter.

2. *Preparation.*—(1) The counter and pipette should be carefully cleaned with water, followed by alcohol and thoroughly dried. (2) Prepare the following solution for diluting blood:

Sod. sulph	gm. 107
Aqua dist	c c. 120

3. *Operation.*—Obtain the blood as described in Lesson LV, allowing it to collect until almost ready to drop. Then insert point of pipette into the drop and by sucking gently draw the blood up to the mark 0.5. Wipe the end of the pipette and insert it into the diluting solution, sucking it up until the bulb is filled to the mark 101. Close ends of pipette with fingers, rolling and shaking it about for a minute. Blow out three drops of the diluted blood. Then drop from the pipette on the round table of the counter just enough of the dilution to cover it when the cover is placed upon it without causing any of the liquid to flow over into the moat. (Fig. 38b). Place the counting slide under the microscope and find the upper left hand square; count all the corpuscles in it. Then count the next square to the right and continue until all the upper row has been counted; write down the number of corpuscles. Then move the counter so that the next lower row can be counted from right to left continuing until all the squares are counted. Clean the counter; agitate the

pipette, blow out a drop, place the diluted blood on the counter and count as before. If the two countings are nearly the same, this will be sufficient; if there is much difference, a third field should be counted and an average taken of the two fields nearest alike. Divide the number of corpuscles by the number of squares; multiply this by 200 to make up for the dilution and then by 400, because each square is equivalent to one four-hundredth of a cubic millimeter. This will give the number of corpuscles per cubic millimeter. Count the corpuscles on

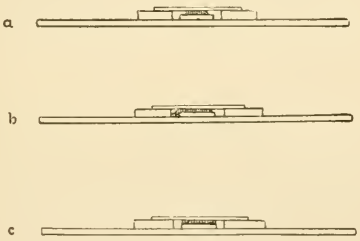


FIG. 38b.

FIG. 38b. Showing the right and the wrong way to fill a Zeiss counting cell. a. Too little blood. b. Too much blood. c. The proper amount of blood.

one-half the boundary of each square but do not count them on the other half.

4. *Precautions.*—See that the blood corpuscles are evenly scattered over the field. (Fig. 39). If they are clustered, it shows faulty technique and the counting dilution must be prepared again with more care. Clean counter and pipette first with water and then with alcohol after using, being careful to leave the tube perfectly dry. The pipette is easily broken. The fine lines on the counter are injured by rubbing with a coarse cloth. The cover glass

should be adjusted before the corpuscles have time to settle.

5. *Observations.*

(1) Make counts of red blood corpuscles from several apparently normal individuals.

(2) Is there any appreciable variation in the number per cubic millimeter?

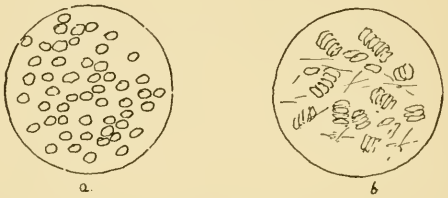


FIG. 39.

FIG. 39. a. Successful blood spread with corpuscles evenly distributed. b. Poor spread with corpuscles clustered.

(3) Can the variation be attributed to faulty methods?

(4) What is the average count for normal individuals?

(5) What is the range between maximum and minimum observations on the normal individuals observed?

(6) Account, if possible, for the variations observed.

LVII. Counting white corpuscles.

1. *Appliances.*—Same as in Lesson LVI with the substitution of the large bore pipette.
2. *Preparation.*—Cut a square out of a circular piece of cardboard which fits in the barrel of the microscope with mechanical stage. The square should be just large enough to bound the counting square of the counting slide. (Fig. 40). Adjust the circular card with the square in

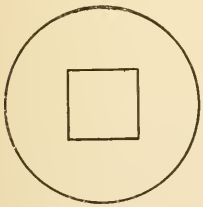


FIG. 40.

FIG. 40. Plan of cardboard diaphragm for microscope tube. For description see **LVII**-2.

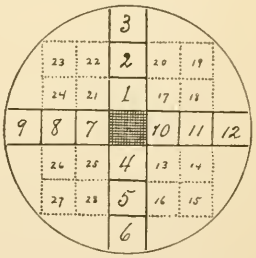


FIG. 41.

FIG. 41. Showing the sequence of the fields counted. For description see **LVII**-3.

it in the upper part of the microscope barrel just below the eyepiece. By lengthening and shortening the microscope the square can be adjusted to the square of the counting slide.

(2) For a diluting solution, use the following :

Acidum acet.....c. c. 4
Aqua dist.. .....c. c. 100

Operation.—Obtain blood as described in exercise LVI and dilute with the above solution. Bring upper line of ruled square to bottom of the square of the field; then the field of the microscope will correspond to field one in the figure. Count all the white cells in the field. Then fix the eye on a cell in the upper margin and bring it to the lower edge of the field; count this field and proceed in the same way to field 3. Turn stage back to ruled space, using the border to indicate where to begin to count. Count fields 4, 5 and 6; turn back to ruled square and proceed

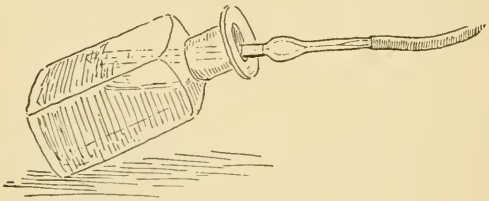


FIG. 42.

FIG. 42. Position of solution tipped to receive pipette horizontally.

to 7, 8, 9; turn back to ruled square and count 10, 11 and 12. For a larger count, proceed in the same manner from the central ruled space to count the additional squares enclosed with dotted lines. The acetic acid in the diluting solution renders the red corpuscles transparent or dissolves them entirely. If this does not so appear, the acid is too weak and more should be used to obtain the desired results.

4. *Precautions.*—Make a good deep puncture. Have a large drop of blood. Remember that the bore of this pipette is larger than that of the pipette for red corpuscles and the solution will run out if the pipette is held perpendicularly. (Fig. 42.) The suction also must be more gentle

than with the small bore pipette. Remember to thoroughly clean and dry the pipette after using.

5. *Observations.*

(1) Estimate the number of white corpuscles per cubic millimeter in several apparently normal individuals.

(2) What is the proportion of white to red corpuscles in each individual?

(3) Is there considerable variation in number of white corpuscles in different individuals?

(4) Is there considerable variation in the proportion between white and red corpuscles in different individuals?

(5) What may cause the variation?

LVIII. Counting red and white corpuscles.

1. *Appliances.*—Microscope with one-seventh objective; needle and holder; Thoma-Zeiss counter with small lumened pipette.

2. *Preparation.*—Prepare the following solution for staining:

TOISSON'S SOLUTION.

Methyl violet, 5 b	.025 gm.
Sod. chlor	1.000 gm.
Sod. sulph	8.000 gm.
Neutral glycerin	30.000 cm.
Aqua dist	160.000 cm.

3. *Operation.*—Obtain blood as described above and dilute 1 to 200 with *Toisson's solution.* Place the counting slide under the microscope and find the upper left-hand square; count the red corpuscles in each square from left to right; then retrace the same field and count the white corpuscles. Repeat this procedure with the next row of squares, continuing the same way until all the squares are counted. Write the number of red corpuscles on one side of a line, the white on the other. Clean the counter; agitate the pipette, blow out a drop, place the solution on the counter and count as before. If there is much variation between the number of first and second field, count a third field and take the average of the two fields nearest alike. Divide the total number of corpuscles by total number of squares counted; multiply by 200 (amount of dilution) and then by 400, which will give number of corpuscles per cubic millimeter. The use of this staining fluid enables the student to count

both red and white corpuscles at the same time instead of counting separately as in Lessons LVI and LVII. This is important to determine the relative proportion of red to white, or white to red corpuscles.

4. *Precautions.*—Extra care must be exercised in cleaning pipette after the use of this staining solution.

5. *Observations.*

(1) Compare the results of this method with those obtained in counting red and white corpuscles separately.

(2) Determine the proportion of white to red corpuscles in a number of normal individuals.

(3) Has age any influence on the proportion?

(4) Has sex any influence on the proportion?

(5) Has the general condition of the nutrition any influence?

(6) Is the proportion always the same in one individual? If not, is there any periodicity in the changes?

(7) Determine, if possible, the causes of the variation.

LIX. Centrifugalizing the blood. To determine the relative volume of red corpuscles and plasma.

1. *Appliances.*—Daland's hæmatocrit (Fig. 43); small rubber tubing to fit capillary tube; needle and holder; vaselin; white paper.
2. *Preparation.*—Adjust rubber to capillary tube. Put empty tube in one arm of crosspiece to preserve balance.
3. *Operation.*—Obtain blood from the lobe of the ear as heretofore described. Draw capillary tube full of blood. Grease the finger with vaselin and hold over the free end of the tube before drawing off the rubber. Place the tube in the crosspiece of the instrument as quickly as possible and revolve at least two minutes at the rate of seventy turns per minute. Take out the tube and lay on a piece of white paper to read the divisions. Each degree of the scale is estimated to contain about 100,000 cells; hence, a tube in which the red column stands at 50 would indicate about 5,000,000 red corpuscles per cubic millimeter. The use of this instrument is designed chiefly to show *the volume of red corpuscles rather than the number*, as shown by the Thoma-Zeiss counter.
4. *Precautions.*—See that the instrument is securely attached to the table and the crosspiece to the instrument before setting it in motion.
5. *Observations and Problems.*
   (1) Determine the volume per cent of red blood corpuscles in a number of normal individuals.
   (2) Do apparently normal individuals have the same or

approximately the same volume per cent of red blood corpuscles. If not, seek for causes for the differences in different individuals.

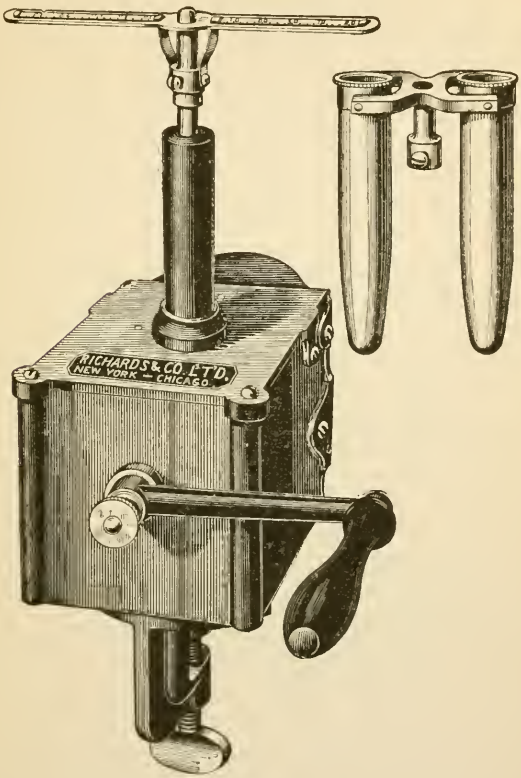


FIG. 43.

FIG. 43. Hæmatocrit.

(3) Does the same individual have the same volume per cent of red blood corpuscles all the while?

(*a*) If there is a variation is there any periodicity to be observed?

(*b*) Seek for causes of any variations in the same apparently normal individual.

(4) The volume per cent as recorded by the hæmatocrit varies with the product of two factors; the average volume of the individual corpuscles multiplied by the number of corpuscles per unit volume. ($V \propto v \times n$)

(*a*) Is the average volume of the individual corpuscles (v) necessarily constant?

(*b*) If it is not constant, would one be justified in drawing conclusions regarding the number of corpuscles per unit volume (n) after observing the volume per cent (V) with the hæmatocrit?

(5) What variation of the observation as above made would enable one to determine with reasonable accuracy the number of corpuscles per cubic millimeter?

LX. Estimation of hæmoglobin.

1. *Appliances.*—v. Fleischl's hæmometer; medicine dropper; distilled water; needle and holder; capillary tube; lamp.
2. *Preparation.*—See that the capillary tube is perfectly clean and dry; if there is any doubt, draw a thread wet with ether and alcohol through it. Fill one side of the metallic cell about one-quarter full of distilled water.

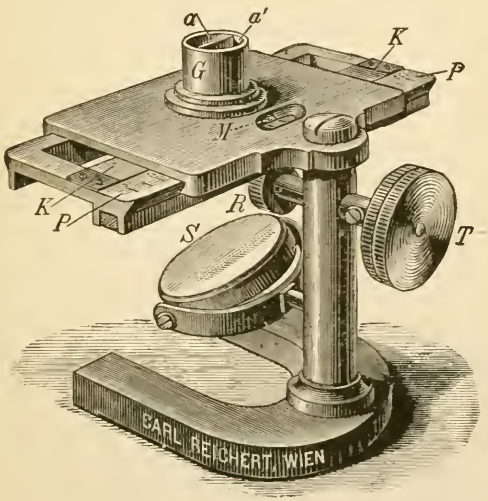


Fig. 44.

Fig. 44. Fleischl's Hæmometer.

3. *Operation.*—Puncture the ear and obtain blood drop. Just touch outside of drop with capillary tube held in a horizontal position; it should quickly fill by capillary attraction. Carefully and quickly wipe away any blood

that may be on the outside of the tube. Plunge it into the well of water, shaking it back and forth to thoroughly mix the blood and water. With the medicine dropper wash the tube with a few drops of distilled water; then remove the tube and draw the solution in and out of the dropper several times to be sure it is well mixed. Then fill both compartments to the brim with the dropper, taking care that the mixture of blood and water shall not flow over into the pure water. Exclude daylight, and by artificial light adjust the compartment containing clear water, so that it comes over the slip of colored glass. Adjust the reflector so that light is thrown up through the well. Then adjust the slip of colored glass until it corresponds with the color of the diluted blood and read the amount indicated by the scale. This will give the percentage of hæmoglobin, 100 being the standard for normal blood.

Any approximate success with this instrument presupposes a color sense. Even when this is present in the student, the instrument itself is not entirely reliable as there is sometimes a variation in the colored slips of glass. It is also not reliable for percentages of hæmoglobin under 20.

4. *Precautions.*—The capillary tube should be cleaned by drawing through it a thread wet with alcohol and ether. The tube must be filled and emptied quickly to prevent coagulation. In reading the instrument, do not face the light but let it come from the side. The instrument should be so placed that the wedge will not move from left to right but to and from the operator. Use as little light as possible. Use first one eye and then the other. Move the screw with quick turns rather than a gradual motion, as the impression of a glance is better than a prolonged look.

5. Observations and problems.

(1) Determine in the cases of several normal individuals whether the blood is normal when compared with v. Fleischl's arbitrary scale. Let the same observer make two or three consecutive tests of the blood of each subject.*

Record for each subject the average of the two or three tests made by one observer.

(2) Account, if possible, for any variations found.

(3) Do the individuals who show a low hæmoglobin reading show also a low volume per cent, and conversely? If so, would one be justified in the conclusion that *the hæmoglobin varies as the volume per cent of the red blood corpuscles?*

(4) Do the individuals who show a low hæmoglobin, reading, show also a smaller number of red blood corpuscles per unit volume, and conversely? If so, would one be justified in the conclusion that the *hæmoglobin varies as the number of red blood corpuscles per unit volume?*

(5) Are there any conditions in which both of these conclusions may be consistent with the results of the reasoning at the end of the previous exercise, LIX?

* If the same observer obtained approximately the same reading on the second and third test of an individual's blood it may be taken for granted that for comparison with each other this observer's readings are sufficiently reliable.

LXI. The microscopic technique of hæmatology. a. Spreading blood. b. Fixing and staining.

a. "Making the spread."

1. *Appliances.*—Microscope with one-seventh objective; needle and holder; square cover glass, $\frac{7}{8}$ inch.
2. *Preparation.*—Clean six or more cover glasses with dilute acetic acid, soap and water, and alcohol.
3. *Operation.*—Puncture the ear and obtain blood as described in Lesson LV. Hold a cover glass in each hand

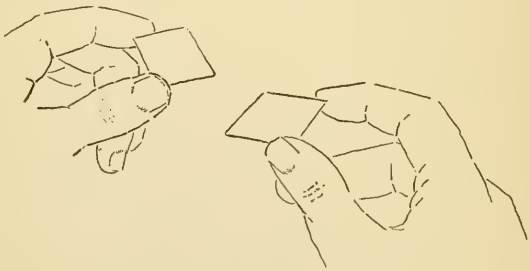


Fig. 45.

Fig. 45. Showing the way to hold the cover glasses.

as shown in Fig. 45. With the one held in the left hand just touch the center to the bottom of the drop, as in Fig. 46, being careful not to touch the ear. Quickly place upon it the cover glass held in the right hand as in Fig. 47. If the blood is fresh and the glasses clean, it will spread rapidly and evenly by capillary attraction. The instant it stops spreading seize the upper cover glass with the right hand as shown in Fig. 48, and pull it quickly apart horizontally. lace the cover glasses,

smeared side up, to dry. When dry, examine with a one-seventh objective. It requires considerable practice and skill to make a good spread, although the operation seems simple enough. In a good spread, the red cells



FIG. 46.

FIG. 46. Touching the cover glass to the blood drop.



FIG. 47.

FIG. 47. Dropping cover glass upon the drop of blood.

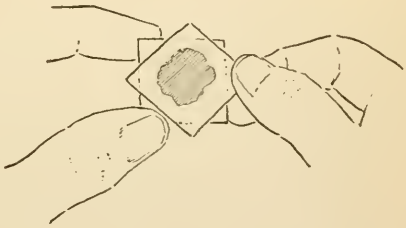


FIG. 48.

FIG. 48. Showing manner of holding the cover glass to jerk them apart.

are evenly distributed, as in Fig. 37. In a poor spread, the cells are clustered, and new spreads should be made until the desired result is obtained.

4. *Precautions.*—Care must be taken to have just the proper amount of blood; too little will not spread well and too much makes the spread too thick to examine well. The blood should not have time to coagulate. The cover glass should not touch the ear in obtaining the blood. The blood can be made to flow again after it has stopped by rubbing the ear briskly with a cloth.

b. Fixing and staining.

1. *Appliances.*—Cover glasses; solution for staining; heater.

2. *Preparation.*—Clean cover glasses carefully with soap and water, followed by alcohol. Instead of a copper plate (Fig. 49) or oven over a Bunsen burner usually used in laboratories, a heater as shown in Fig. 50 is rec-

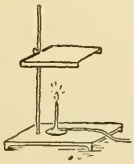


FIG. 49.

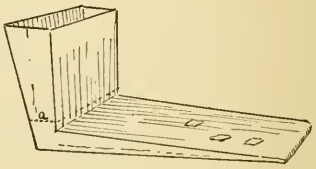


FIG. 50.

FIG. 49. Common copper heating plate.

FIG. 50. The water fixing plate.

ommended. Cover glasses should be dried at boiling point, which is constantly maintained in this heater, it being filled with water and placed over a burner. There is no danger of scorching, as there is on the strip of copper over the Bunsen burner. With the pattern and dimensions given in Fig. 51, any tinsmith can quickly make the heater out of copper.

(2) Prepare the following solution for staining:

Ehrlich-Bondi powder (Grübler).....	1 gm.
One-half per cent sol. acid fuchsin.....	5 c c.
Aqua dist.....	25 c.c.

Let this solution stand one week and filter.

3. *Operation.*

(*a*) Obtain and spread blood as described in section **a**.

(*b*) Place the cover glass, spread side down upon the heater and maintain at 100°C. for fifteen minutes. This process dries and fixes the preparation.

(*c*) Remove the fixed preparation; cover the film with staining solution, allowing it to remain from six to ten minutes. The time of staining depends upon the length of time the film has been heated; a film fixed quickly will stain more readily.

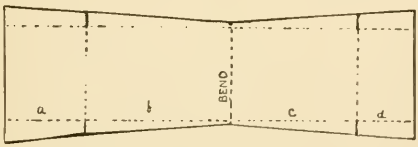


FIG. 51.

FIG. 51. Plan for constructing the water fixing plate.

(*d*) Rinse off the excess of stain in pure water and dry.

(*e*) Mount in balsam.

4 *Precautions.*—Be sure that the water in the heater is boiling before placing the films upon it. Do not let the water boil too violently or it may boil over and spoil the films. The films must be air dried before they are placed upon the heater.

LXII. Differential counting of white cells and of red cells.

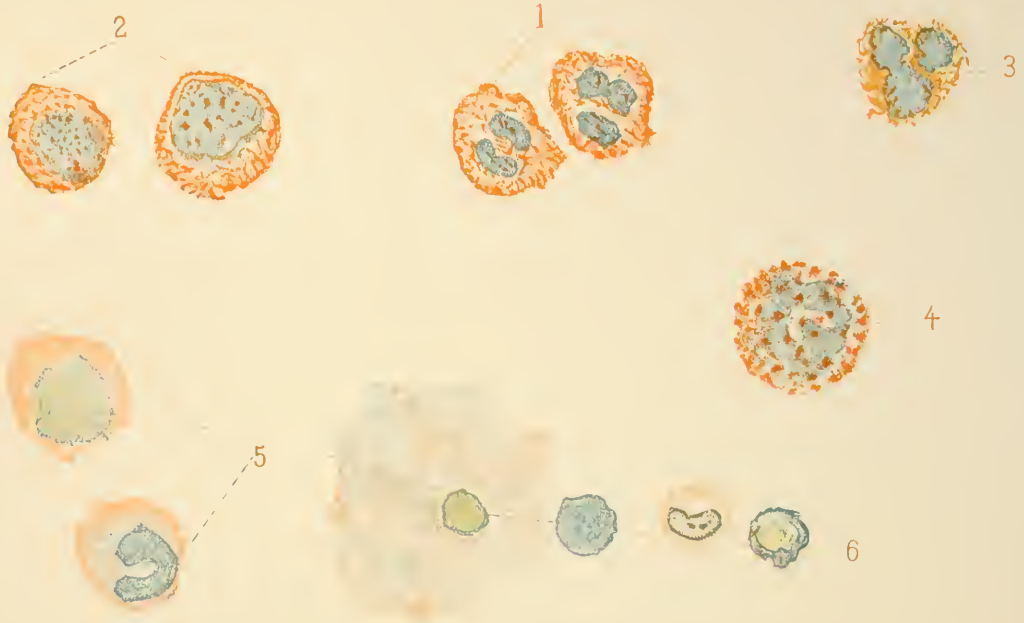
1. *Appliances.*—Microscope with one-twelfth oil immersion lens; mechanical stage (not essential but convenient).
2. *Preparation.*—Stain as in Lesson LXI. Write the names of varieties of cells, which may become familiar to the eye by the study of the colored plate, and as each different cell is discovered, record that fact by a check.
3. *Operation.*—Begin at the upper left corner of the specimen and count toward the right the different cells as they come into view. When the right border comes into view move the specimen so that the adjoining lower field is brought into range and count back again. Mark the cells found under their proper heads. After the observer has become familiar with the different cells he can keep in mind the neutrophiles for the entire trip across the field, but the others he had best mark as soon as found.

Varieties of leucocytes. (Fig. 52 a.)

Polymorphonuclear neutrophiles. (Neutrophiles.)
Myelocytes,
Small lymphocytes,
Large lymphocytes,
Eosinophiles,
Eosinophilic myelocytes.

Varieties of red cells. (Fig. 52 b.)

Normoblasts,
Megaloblasts,
Microblasts,
Macrocytes,
Microcytes,
Poikilocytes,
Polychromatiphilic cells.



52a. Varieties of Leucocytes.

1. Polymorphonuclear Neutrophiles.
2. Myelocytes.
3. Eosinophile.
4. Eosinophilic Myelocyte.
5. Large Lymphocytes
6. Small Lymphocytes



52b VARIETIES OF RED CELLS

1. Normal Red Cells
2. Normoblasts
3. Microblasts
4. Megaloblasts

LXIII. Study of bone marrow.

1. *Appliances.*—Strong vice; five-eighths inch cover glasses; microscope; heater; Ehrlich's triple stain (See Lesson LXI); section of bone containing red marrow; saw.
2. *Preparation.*—Clean cover glasses as usual and have water in heater or fixing-plate boiling.
3. *Operation.*—Saw a transverse section of bone one inch thick. Place it in the vice and turn the handle until the bone marrow begins to ooze out on the surface. Just touch the surface of this with one of the cover glasses and proceed exactly as in exercise **LXI a**, making as good a blood spread as possible. Dry smeared side up. Then fix and stain as described in **LXI b**. Place slide under the microscope and make a differential count of red and white cells as in **LXII.**
4. *Precaution.*—Have the bone specimen as fresh as possible. Saw the piece to be used just before putting it in the vice and then take the specimen from the freshest side of the bone.
5. *Observations.*
   (1) What cells do you find that are not found in normal blood?
   (2) Can you trace these cells to the cells of normal blood?

PHARMACOLOGY.

H. AN INTRODUCTION TO PHARMACOLOGY.

By H. M. Richter, M. D.

INTRODUCTORY.

While the following experiments will more forcibly impress the student's memory with the action of the drugs under consideration than any didactic lecture possibly could, this must be considered as of secondary importance. The real object is to teach pharmacological technique—to place the student in a position where he can at any time in the future demonstrate experimentally to his own satisfaction the activity or inactivity of any drug, and its modus operandi.

With this object in view, experiments have been chosen which can readily be performed by the student himself. No attempt is made to show the various actions of each drug used, but, instead, the most conspicuous and easily demonstrated action of each is utilized. Considerable time is expended on the reflex arc, because the action of drugs on its different elements is most readily demonstrated.

Little can be found concerning the doses to be used in experiments. In order to save time and trouble, the dose to be used in each of the following experiments is given.

The student is presumed to have a fair working knowledge of the technique of the physiological laboratory. The use of the myograph, kymograph, etc., the setting up of electrical apparatus, such as batteries, inductorium, commutator keys, and the use and effects of same. As to the literature on the subject, the following are valuable, and have been made free use of:

Smith's translation of L. Hermann's "Experimental Pharmacology" is the only English work devoted to technique; Brunton, "Pharmacology, Therapeutics and Materia Medica," and "Pharmacology and Therapeutics;" White, "Materia Medica and Therapeutics;" Stirling, "Practical Physiology;" Landois and Stirling, "Textbook of Human Physiology." These comprise most of what has been written on the subject in English.

Each group of students will need the following apparatus and material for the experiments:

One Daniell cell;
Inductorium;
Myograph;
Kymograph;
Contact key;
Two frog boards and stands;
Shielded electrodes;
Physiological operating case;
Clippers;
Hypodermic syringe;
Commercial curare;
Hydrochlorate of pilocarpin;
Sulphate of veratrin;
Tincture of aconite;
Dog and rabbit holder;
Seeker; Pins;
Pin-pointed pipette;
Fine and coarse thread;
Normal saline solution;
Gutta-percha tissue;
Chloroform;
Ether (common sulphuric);
Sulphate of morphin;
Sulphate of atropin;
Sulphate of strychnin;
Ticture of digitalis;
Sodic carbonate;
Sodic sulphate.

LXIV. Curare.

1. *Material.*—One dog; 2 frogs; sodic chloride; curare.
2. *Preparation.*

Prepare following solution of sodic chloride, 0.06 grms. to 10 c. c.; curare, 0.1 grm. to 10 c. c. Pith frogs. Do not fasten the dog to the board, but simply restrain him. Set up inductorium and myograph, the former so as to obtain single induction shocks.

3. *Experiments and observations.*

(1) Give a hypodermic injection of 0.02 grm. curare to the dog.

(*a*) Record the condition of the dog just before, and every ten minutes after injections of curare with special reference to:

(I) Muscular activity.

(II) Respiration—number and depth.

(III) Circulation—rate and rhythm of heart-beat.

(IV) Which stops sooner, respiration or circulation?

(*b*) Formulate the total effect of curare upon the animal.

(2) Ligate the thigh of a frog, except the sciatic nerve, near the knee-joint.

Inject into the dorsal lymph space 0.0012 grms. curare.

(*a*) What elements enter into the formation of a "*reflex arc?*"

(*b*) What motor phenomena would result from increased irritability of any part of the reflex arc?

(*c*) What motor phenomena would result from les-

sened irritability or destruction of any element in the reflex arc?

(*d*) What effect has the ligature of the thigh on the distribution of the curare?

(*e*) How do the reflex arcs, of which the gastrocnemii are the motor ends, differ with regard to the distribution of the curare? What part of the reflex arc is protected from curare in the ligatured limb?

(*f*) Describe the relative reaction of the gastrocnemii to stimuli (chemical, mechanical, electrical) applied to various parts of the body and limbs.

(*g*) Is the sensorium intact? Is it reached by the curare?

(*h*) Is the cord intact? Is it reached by curare?

(3) Expose the sciatic nerves, near the body, in the frog used in experiment (2); stimulate them.

(*a*) What elements in the reflex arc enter into consideration in this experiment?

(*b*) Which of these elements are exposed to, which protected from the poison?

(*c*) Are both sciatics reached by curare?

(*d*) Is there a difference in the reaction of the gastrocnemii to the stimuli applied to the sciatic nerves?

(*e*) To what elements of the reflex arc have you limited the possible action of the curare?

(*f*) Have you proven that curare does not affect the nerve trunks?

(4) Expose gastrocnemii by cutaneous incision. Stimulate the muscles directly.

(*a*) Is there a difference in reaction to stimuli?

(*b*) If a muscle in a poisoned animal reacts to direct stimuli, but not to indirect stimuli, though the nerve fibers be proven to be intact, on what element in the reflex arc must the poison act?

(*c*) Why would you not use curare as an anæsthetic if the poisoned animal does not react to painful stimuli?

(5) Make two muscle nerve preparations as described on page 56. Dip the nerve of one, and the muscle of the other into curare solution. The parts of the preparations not immersed should be kept moist with normal saline solution. After several minutes mount specimens in the myograph. Stimulate the nerves and note:

(*a*) The relative reaction of gastrocnemii to indirect stimulation.

(*b*) Does this bear a resemblance to any previous experiment?

(*c*) How do results compare with those of previous experiment?

(6) Stimulate the same muscles directly.

(*a*) Relative reaction?

(*b*) Taking this in connection with preceding experiment, where have you proved that curare acts?

(*c*) How do experiments (5) and (6) compare with experiments (3) and (4)?

NOTE:—Failure in experiments (5) and (6) may result from insufficient immersion of muscle in curare solution, capillary attraction resulting in curare reaching muscle supposed to be free from poison, and drying of parts not immersed in solution. Of these the first is by far the most frequent cause of failure, the sheath of the muscle rendering the absorption of poison a slow process. It may be overcome by making a few slight incisions in sheath, or injecting a drop of the curare solution directly into the muscle.

Failure of experiment (2), and consequently (3) and (4), may result from ligature around thigh being not tight enough to prevent diffusion of curare into gastrocnemius.

LXV. Atropin.

1. *Material.*—2 dogs; atropin sulphate; morphin sulphate; chloroform (or ether); mask.
2. *Preparation.*—Make up following solutions; a strong solution of atropin 0.4 grm. to 10 c. c.; a weak solution, 0.02 grams to 10 c. c.; morphin, 0.6 grams to 10 c. c.

   Simply restrain dog "a." Fasten dog "b" to board. Give hypodermically, 0.03 grm. morphin to dog "b," then anæsthetize him. Set up induction coil so as to obtain interrupted current.
3. *Experiments and Observations.*

   (1) Drop three drops of the stronger atropin solution into one eye of dog "a," allowing them to drop in at short intervals, and obstructing tear duct with pressure of finger.

   (*a*) What is the nerve supply of the iris?

   (*b*) On what local elements may a drug act to produce alteration in size of pupil, and how?

   (*c*) Would a drug, acting centrally, though applied to one eye, be likely to affect one, or both pupils?

   (*d*) Would a drug, acting locally, and applied to one eye, be likely to affect one, or both pupils?

   (*e*) Would a drug, acting locally on the pupils, but injected into the circulation, and reaching the pupils in this way, be likely to act on one, or both pupils?

   (*f*) Are either or both pupils affected by atropin, and if so, what effect is produced?

   (*g*) Does atropin act locally or centrally to produce its effect on the pupil?

(*h*) Can you devise an experiment that would positively answer question "g."?

(2) Expose the vagus of dog "b" (see pp. 110-111). Stimulate it with weak induced current, using shielded electrodes.

(*a*) What is the function of the cardiac fibers of the vagus?

(*b*) How, therefore, would you expect stimulation of the vagus to affect rate and rhythm of the heart beats?

(*c*) How would you expect severing of the vagus to affect the rate and rhythm of the heart beat?

(*d*) How do you actually find the rate and rhythm of the heart beats affected by stimulation of the vagus?

(3) Count the pulse, then give 5 mgrm. atropin hypodermically.

(*a*) Count the pulse at short intervals after the injection of atropin for at least 30 minutes, or until its rate is markedly affected.

(*b*) What is the effect of atropin on the rate of the pulse?

(*c*) Could atropin produce this effect by acting on the vagus center? On the vagus fibers? On the vagus terminations in the heart? On the heart muscle direct?

(4) After the pulse rate has been markedly affected by atropin stimulate vagus as before, using shielded electrodes.

(*a*) What is the effect on the rate of heart's action?

(*b*) Compare this result with that obtained in experiment (2).

(*c*) Had atropin acted solely by depressing the vagus center would we have found a difference in results

in stimulating vagus nerve before and after its exhibition?

(*d*) Had atropin acted on the accelerator apparatus would there be a difference in such results?

(*e*) If now, on stimulating the heart muscle directly, you obtained a normal physiological effect, to what elements have you limited the possible action of atropin?

(*f*) Basing your opinion on the experiments you have performed, to what elements have you limited the possible action of atropin?

(5) Further general observations.

(*a*) Take temperature per rectum.

(*b*) Note condition of visible mucous membranes, with regard to their secretions.

(*c*) If dog can be kept until next day, note size of pupils.

LXVI. Pilocarpin.

1. *Material.*

1 rabbit; 1 dog; hydrochlorate of pilocarpin; sulphate of morphin; sulphate of atropin; chloroform.

2. *Preparation.*

Make solution of pilocarpin, 50 mgrms. to 10 c.c.; atropin, 0.02 grm. to 10 c.c.; morphin 0.6 to 10 c.c.

Do not fasten the rabbit to the holder. Fasten the dog to the dog board, after giving preliminary hypodermic injection of 0.03 grms. morphin.

3. *Experiments and Observations.*

(1) Give, hypodermically, 0.02 grm. pilocarpin to the rabbit.

(*a*) Record symptoms as they arise, especially as regards:

(I) Secretions;

(II) Pulse rate;

(III) Size of pupil;

(IV) Temperature.

(*b*) Formulate the total effect of pilocarpin upon the animal.

(2) After morphinizing the dog, fasten it firmly to the dog-board and lightly anæsthetize; expose both vagi.

Count the pulse. Give a subcutaneous injection of 0.03 grms. pilocarpin. After salivation has become profuse count the pulse again.

How does pilocarpin affect the pulse rate?

(3) Now sever the vagi.

(*a*) How does the severing of the vagi affect the normal animal? (See page 109.)

(*b*) How does it affect an animal poisoned by pilocarpin?

(*c*) Could pilocarpin alter the effect produced by severing the vagi if it acted on the proximal side of the point at which the vagi were cut? On a point beyond that at which they were cut?

(*d*) Could the pilocarpin alter the effect normally produced by severing the vagi, by acting on the cardiac sympathetic?

(*e*) Enumerate the possible points at which pilocarpin may act to produce the effects observed.

(4) Give to the same dog 5 mgrms. atropin, hypodermically.

(*a*) Is the rate of heart-beat altered?

(*b*) Where does atropin act to produce alteration in rate of heart-beat (see atropin.)

(*c*) Does atropin antagonize the action of pilocarpin in this experiment?

(*d*) To what elements have you limited the probable action of pilocarpin?

(5) General observations.

(*a*) Compare the action of pilocarpin with that of atropin, throughout the range of action observed.

(*b*) Is atropin a *physiological* antagonist to pilocarpin?

LXVII. Strychnin.

1. *Material.*—One dog; two frogs; sulphate of strychnin.
2. *Preparation.*—Make a solution of sulphate of strychnin 0.01 gm. to 10 c. c.; also concentrated solution, 0.2 gm. to 10 c. c. Pith frogs. Do not fasten the dog to the dog-board. Set up electrical apparatus to obtain tetanizing current.
3. *Experiments and Observations.*
   (1) Hypodermic injection of 0.01 gm. strychnin to the dog.
      (*a*) Record the condition before, and symptoms as they arise after exhibition of the drug, especially with reference to:
         (I) Muscular activity. Describe convulsions.
         (II) Respiration. How affected by reflexes.
         (III) Circulation. Rapidity and rhythm of heart.
         (IV) If death occurs, which stops sooner, the circulation or respiration?
      (*b*) Formulate results.
   (2) Ligate thigh of frog, except sciatic nerve, at junction with body. Sever all structures except nerve and femur, just below ligature. Separate cut surfaces with rubber tissue to prevent diffusion of the drug. Turn the frog over and make a median abdominal incision. Pressing viscera aside, pick up the sacral plexus of nerves going to the uninjured leg. The sacral plexus may be readily recognized, lying on each side of the median line. Pass a thread loosely around the nerves, so as to quickly find them when wanted. Inject into dorsal lymph space, 0.0001 gm. strychnin.

(*a*) What part of the frog is reached by the poison? What part protected from it? Illustrate by diagram.

(*b*) Were strychnin a convulsant through its action on the sensorium, would the legs be equally convulsed? If it acted on the spinal cord? If it acted on the motor nerves? If it acted on the muscles directly?

(*c*) Are both legs convulsed?

(*d*) To what parts in the reflex arc have you limited the action of the strychnin?

(3) Using as a guide the thread formerly passed around it, pick up sacral plexus and sever it high up.

(*a*) Does the strychnin reach the motor nerve and muscles of uninjured leg?

(*b*) If strychnin were a convulsant through its action on either the motor nerves or the muscles, or both, would the uninjured leg still participate in the convulsions?

(*c*) Demonstrate that muscles, sciatic nerve and sacral plexus below the point at which it was severed, are still intact, by stimulating distal portion of latter.

(*d*) To what elements of the reflex arc have you limited the possible action of strychnin?

(4) Expose the heart of a frog and ligate the aortæ at the base. Operation as follows:

Freely expose sternum by + shaped incision and laying back of flaps. Remove lower half of sternum with scissors, taking care not to injure vessel in abdominal wall which comes just to tip of sternum. Freely incise exposed pericardium, bringing heart into view. Grasp apex of heart with forceps, taking care not to use force enough to cut through ventricular wall, and draw heart down and forward. This gives ready access to bulbus arteriosus and aortæ. With an aneurism needle pass fine thread around latter, taking care not to injure auricles, and ligate.

With scalpel cut through occipito-atlantoid membrane, from side to side, and bend head forward. Remove posterior wall of upper end of

spinal canal by inserting smaller blade of strong scissors into spinal canal and cutting, taking care not to injure cord. Allow a drop of the concentrated solution of strychnin to fall directly upon cord; or with fine hypodermic needle inserted 1.5 cm into the arachnoid space inject two drops of the solution.

(*a*) What effect has ligation of the aortæ on the circulation?

(*b*) Would stoppage of the circulation prevent the drug from reaching the peripheral terminations or trunks of the sensory nerves? Motor nerves? Muscles?

(*c*) Where then, must strychnin act to produce the observed symptoms?

(*d*) Would cessation of the circulation delay the action of strychnin on the cord by slowing the rate of its absorption by the latter?

(5) After observing results in experiment (4), destroy first the upper then the lower portion of the cord, by passing a wire down the spinal canal.

(*a*) How does destruction of the upper part of the cord affect the convulsions?

(*b*) What is the result of the destruction of the entire cord?

(*c*) Do the results agree with those of previous experiments?

NOTE :—Destruction of the upper part of the cord during the preparation of the animal may take place; if so, the upper limbs will not take part in the convulsions.

(6) Further observations and comparisons.

(*a*) Compare the general effects of strychnin and curare in the dog.

(*b*) Compare results obtained in experiments consisting of ligating the thigh of a frog except the sciatic nerve, and injecting, in the one case strychnin, in the other curare.

LXVIII. Veratrin.

1. *Material.*—Sulphate of veratrin; 1 dog; 3 frogs.
2. *Preparation.*

Prepare a solution of veratrin, 50 mgrms. to 10 c.c. Pith frogs. Restrain dog, but do not fasten to board. Set up myograph and induction coil, the latter arranged for single induction shocks.

3. *Experiments and Observations.*

(1) Give a subcutaneous injection of 15 mgrm. veratrin to the dog.

(*a*) Describe symptoms as they arise.

(*b*) Summarize.

(2) Place thread around the sacral plexus of the pithed frog so as to easily find it, as described under strychnin. Inject 0.003 gms. veratrin into dorsal lymph space.

(*a*) Describe symptoms referable to rexflexes.

(*b*) Note particularly the difference between a *forcible* contraction and a *prolonged* contraction.

(3) Sever the sacral plexus around which the thread has been passed.

(*a*) How do the contractions of the legs in response to direct stimuli compare?

(*b*) Has severing the sacral plexus altered the *duration* of the contraction of the muscles supplied?

(*c*) If veratrin still produces its typical effects, to what elements in the reflex arc have you limited its action?

(*d*) Compare the effect of severing the sacral plexus in a frog poisoned with veratrin with that in a frog poisoned with strychnin.

(4) Ligate the thigh of a pithed frog at the junction with the body, not including in the ligature the sciatic nerve. Sever all tissues just below the ligature except the nerve and the femur. Carefully separate the cut surfaces with rubber tissue so as to prevent diffusion of the drug. Inject 0.003 gm. veratrin into the dorsal lymph space.

(*a*) By means of a diagram show the distribution of the poison.

(*b*) Compare the contractions of the legs, noting particularly the difference in the *duration* rather than the difference in the force of the contraction.

(*c*) If the protected limb reacts normally to stimuli, to what elements in the reflex arc have you limited the possible action of veratrin?

(*d*) Compare results with similar experiment with strychnin.

(5) From the frog used in experiment (4) make two gastrocnemii preparations. Fasten in myograph by means of femurs, and stimulate them directly, making tracings of contractions.

(*a*) Compare tracings.

(*b*) To what elements have we limited the action of veratrin?

(*c*) Suggest an experiment which would limit the action to one element.

(6) Very cautiously sniff veratrin. Describe the sensasation.

(7) General observations and comparisons.

(*a*) Review your notes on the action of curare, strychnin and veratrin upon the reflex arc.

(*b*) How would you prove that a drug paralyzed by its action on the spinal cord?

(*c*) How would you prove that a drug destroyed reflex activity by its action on some part of the sensorium?

LXIX. Digitalis.

1. *Material.* — Tr. digitalis; sulphate of morphin; sodic chloride; chloroform; two dogs; one frog; sodic sulphate (½ sat. sol.).
2. *Preparation.* — Make solution of morphin, 0.6 gm. to 10 c. c. Sodic chloride, 0.06 gm. to 10 c. c. Pith frog. Morphinize dogs, using 0.03 gm. and chloroform them previous to operation. Set up induction coil so as to obtain tetanizing current, having contact key in primary circuit. Prepare kymograph for tracing.
3. *Experiments and Observations.*

(1) Fasten a dog firmly to the dog board and lightly anæsthetize. Expose the vagus. Count the pulse. Using shielded electrodes and separating secondary from primary coil, find a current just weak enough not to affect heart when applied to vagus. Now inject 0.6 c. c. tr. digitalis subcutaneously. After waiting at least 20 minutes, in the meantime using no anæsthetic except a repetition of the morphin if necessary, and keeping the wound closed after moistening with saline solution, stimulate the vagus with same current that before the exhibition of digitalis was unable to affect the heart.

(*a*) What is the function of the cardiac fibers of the vagus?

(*b*) What result is produced by the stimulation of these fibers in the normal animal?

(*c*) Does digitalis increase or decrease the excitably of the vagus?

(*d*) With the stimulus applied to the vagus fibers and

the cardiac fibers carrying impulses centrifugally, could this altered excitability be due to central action of the digitalis?

(2) After morphinizing dog, fasten firmly to dog board and lightly anæsthetize; expose femoral artery.

Having placed mercury in the manometer, and filled the cannula, connecting tube and short arm of the manometer with ½ saturated sodic sulphate solution, to prevent clotting, insert the cannula into the femoral artery, in a direction toward the heart. There must be no air bubbles in the apparatus at any point. Let the float, carrying the tracing point, rest on the mercury in the long arm of the manometer and record on the revolving drum.

The anæsthetic should be discontinued as soon as the cannula is inserted into the femoral artery. Take normal tracing. Now give the dog 0.6 c. c. tr. digitalis hypodermically.

(*a*) Watch effect on elevation of float, making tracings at short intervals.

(*b*) What elements enter into arterial tension?

(*c*) How does a "high tension" tracing differ from a "low tenison" tracing?

(*d*) How do changes in tension affect the elevation of the tracing above the abscissa?

(*e*) What effect has digitalis on arterial tension?

(3) Having firmly fastened a pithed frog to frog board with web stretched over a cover glass fastened into a hole in the board by means of sealing wax, focus the microscope upon a certain arteriole in the field, and measure its diameter with an eye-piece micrometer. Now inject into dorsal lymph spaces 0.3 c. c. tr. digitalis and measure same arteriole at intervals of 10

minutes. Keep the web moist with normal saline solution.

(*a*) What change occurs in the diameter of the arteriole?

(*b*) What effect would you expect this to have on arterial pressure?

(*c*) Would its action on the arterioles help to account for its effect on arterial pressure?

(4) *Comparisons.*—Compare digitalis and atropin with regard to (a) their effect on the rate of the heart beat. (b) Their effect on the irritability of the vagus.

LXX. Aconite.

1. *Material.*—Tr. aconite; sulphate of atropin; 1 dog; 1 frog; sphygmograph.
2. *Preparation.*

   Make solution of atropin, 0.02 grms. to 10 c.c. Pith frog. Do not fasten the dog to the dog board.
3. *Experiments and Observations.*

   (1) Give 1 c.c. tr. aconite hypodermically to the dog. Record symptoms as they arise.

   (2) Fasten the pithed frog on its back to the board. Count the heart beats, exposing heart, if necessary. Now give 0.2 c.c. tr. aconite subcutaneously. What effect has aconite on the pulse rate? (To obtain satisfactory results observations must be made at short intervals, for from 30 to 60 minutes.)

   (3) After the pulse has been markedly affected, inject into the dorsal lymph spaces 0.0002 grm. atropin. Does atropin affect the pulse rate after administration of aconite?

   (4) Take a sphygmographic tracing of the radial pulse of a student. Note the pulse rate. Administer, by mouth, 0.2 c.c. tr. aconite and 0.06 c.c. every 10 minutes until action on pulse is noticeable. Repeat tracing and counting of pulse at short intervals.

   (*a*) How does aconite affect blood pressure?

   (*b*) How is the rate of the heart's action affected?

   (*c*) What subjective sensations are produced?

   (5) *Comparisons.*—Compare aconite and pilocarpin with regard to their action on the gastro-intestinal system.

APPENDIX. A.

APPENDIX A.

1. Normal saline solution.

This solution, or as it is also called normal salt solution or physiological salt solution, is so much used in the physiological laboratory that it should be made in considerable quantity and always easily accessible.

Formula:

Common salt (C. P.)	30 gms.
Distilled water	5 L.

It is convenient to keep the solution in a siphon bottle. It is thus protected from dust and evaporation, and is always easily accessible. See Fig. 53.

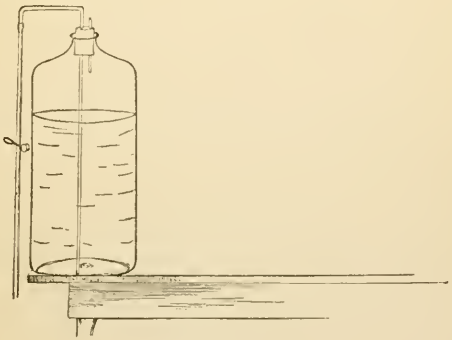


FIG. 53.

FIG. 53. Siphon-bottle for normal saline solution.

2. Frog boards.

There is probably no more satisfactory or economical frog board than a piece of dressed soft pine 15 cm. by 30

cm., and one or two centimeters in thickness. Some prefer to use cork boards which come in pieces 10 cm. by 25 cm. and ¾ cm. in thickness.

3. The physiological operating case.

A convenient case, and one which will be sufficient in the simple experiments presented in this book, contains the following instruments :

1 medium scalpel,
1 small scalpel with narrow blade,
1 medium scissors,
1 microscopic scissors,
1 medium dissecting forceps,
1 microscopic forceps, with curved, serrated jaws,
2 serre fine forceps, with stiff spring and serrated jaws,
1 groove director and aneurism needle,
1 silver probe,
1 blunt needle, for pithing frogs,
2 dissecting needles.

The case may be of leather or leatherette. Such a case may be used nearly as much in the histological as in the physiological laboratory.

4. Galvanic cells.

For general use in the physiological laboratory there is probably no galvanic element superior to the Daniell cell (named after Prof. J. F. Daniell, of King's College, London). Much the most convenient and economical size is the quart or liter cell whose porous cup measures 5–6 cm. in diameter and 10 to 12 cm. in height. If more current is needed than is furnished by one of these cells it is very easy to join two or more of them into a battery.

In large laboratories it will be found expedient to devote an old table to the galvanic cells. This table should

be provided with a supply of copper sulphate and of 10% sulphuric acid in large siphon bottles similar to the one suggested for normal salt solution (Fig. 53), except that instead of the short tube for equalizing pressure one may insert a filter through which at the end of the laboratory period the student may return the liquids.

The accumulation of zinc sulphate in the acid makes the renewal of the acid necessary from time to time. The deposit of metallic copper upon the copper plate reduces the copper sulphate solution in strength. It may be kept replenished by an excess of crystals of that salt in the large supply jar. A very practical method of amalgamating the zinc plates is to have a jar containing 10% sulphuric acid with mercury in the bottom; as the plate is immersed the acid attacks it and cleans it so that the mercury readily clings to it and may be rubbed over the surface with a cloth. Another method, which is preferred by some, is as follows: Dissolve 75 gms. of mercury in a mixture of 150 c. c. strong nitric acid and 300 c.c. strong hydrochloric acid. Add to the solution 450 c.c. of strong hydrochloric acid. Keep this amalgamating solution in a ground glass stoppered jar. To amalgamate a zinc plate one need only dip it for a few moments into the solution, remove it, rinse under the spigot and rub with a cloth.

At the end of each laboratory period the cells should be emptied, the zinc plates rinsed and drained, and the porous cups left in a tray of running water, or at least in a considerable excess of water.

5. To curarize a frog.

In experiments on the irritability of muscle tissue it is necessary to, in some way, suspend the activity of the irritable nerve fibers which are supplied to every muscle. In certain other experiments it may be advisable to thus

remove the influence of the nervous system. *Curara*—also spelled *curare,* curari, urari, and woorara, woorari, wourali, etc.,—an arrow poison used by the South American aborigines, is the means usually employed to accomplish the end desired. The way in which curare exerts its influence, is made the subject of study in another place. Make a 1% solution by pulverizing 1 gramme of commercial curare, and dissolve it in 100 c. c. of distilled water. It need not be filtered unless intended for use with a hypodermic syringe. If kept in a ground glass stoppered bottle, in a cool place, it will retain its efficiency for months.

The most convenient method of curarizing a frog is to inject with a narrow pointed pipette, 1–3 drops of the solution, through a minute ventral cutaneous incision.

The drug will begin to take effect in a few minutes. The maximum effect may be delayed some time.

6. To prepare the kymograph for work.

Remove the cylinder, stretch a sheet of the prepared glazed paper tightly upon the surface, place it upon such a stand as the one shown in Fig. 54; set the drum to

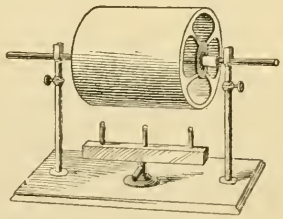


FIG. 54.

FIG. 54. Drum support for use in smoking the kymograph drums.

rotating and bring the triple gas flame under the drum. In a few moments it will be evenly covered with a film of

carbon which is as sensitive to touch as a photographer's plate is to light.

7. A fixing fluid for carbon tracings.

Gum damar..... ....160 gms.
Benzole q. s. ad.....2000 c.c.

If this solution be kept in a large museum jar in the laboratory, the removed sheet bearing the tracings may be dipped *in toto* or it may be subdivided and dipped in sections. Let the tracing be lowered quickly into the solution and after a few seconds taken out and drained. If it be now laid upon a sheet of filter paper—or a newspaper—it will be dry in a few minutes.

8. The cardiograph.

Any laboratory will have different forms of cardiographs for demonstration purposes, but not every laboratory is able to afford numerous duplicates. An expert tinsmith will make the tambour pans at very moderate cost, and the student can do all the rest. Pans may be made of two sizes No. 1, diameter 5 cm., depth 4 mm., outside diameter of tube 3 to 4 mm., length of tube 3 to 4 cm. No. 2, diameter 4 cm., depth 3 mm., tube as in No. 1, see Fig. 55,



Fig. 55.

To make the cardiograph :—Take a tambour pan No. 1, stretch thin sheet rubber—the dentists' "rubber dam," and sold as such by dealers—across the pan and tie in place with thread. A few drops of sealing wax will keep the thread in place after it is tied. Mount the tambour as follows : From any well seasoned, close-grained hardwood in boards, about 1 cm. thick, cut small triangular pieces about 10 cm. on a side. In the center of each triangle bore a hole to receive a medium sized cork (about

1.5 cm. in diameter) the upper edges of the triangle may be beveled and each corner may be furnished with a leg by screwing into each corner from the lower surface, a round headed screw, leaving about 1 cm. of the screw out to serve as the leg. If the class is large, the demonstrators should prepare these tambour boards in advance. The tambour is mounted by fitting a cork to the hole in the tambour board, boring the cork and pressing the tambour tube through the hole from below upward. Fix a button of cork to the membrane with sealing wax. The completed cardiograph will present in section the relations shown in Fig. 56. As will be seen from the cut, the position of the button may be varied by varying its shape or by changing the adjustment of the tambour tube in the cork. The cardiograph tambour is *the receiving tambour*.

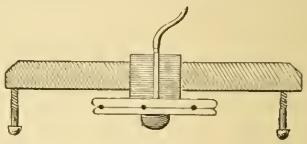


FIG. 56.

9. Tambours.

It is probable that no part of the laboratory equipment is more in use than the various forms and adjustments of the tambour. The possibilities of this device were first brought out and developed by Marey, Director of the Physiological Institute of the École des Hautes Etudes *en Sorboune*, Paris.

If the laboratory cannot afford to furnish at least one pair of the Marey tambours to each table, recourse may be had to such a device as that just described above under the cardiograph. Such simple tambours when carefully constructed prove most satisfactory.

To construct a recording tambour: Use a No. 2 tambour pan, stretch the rubber less tightly than for the receiving

tambour and mount similarly in a triangular tambour board, omitting the screw legs. Make a recording needle like the frog's heart lever, except that the foot, which rests upon the middle of the tambour membrane, should present a larger surface. The cork which forms the fulcrum of the lever should be fixed to the tambour board in such a position that the long arm of the lever is vertically above a diameter of the tambour. Any change of pressure upon the air in the tambour will cause the membrane to rise or fall, thus producing in the tracing point of the lever a corresponding rise or fall, differing from that of the membrane only in its greater extent. It is evident that if the tube of the receiving tambour be joined to the tube of the recording tambour through a thick rubber tube any movements which affect the button of the first will be manifested by a rise or fall of the lever which rests upon the second.

10. The stethograph.

In order to record graphically the movements of the chest one may use various mechanical devices. The most simple device, and a most effective apparatus, when only the time relations and the character of the movements are matters of concern, is the instrument which involves the use of two tambours, a receiving and a recording tambour. The latter is the one describedab ove, (9.)

A receiving tambour may be constructed especially for this purpose as follows: Let a tinsmith construct, from small brass wire, (½--¾ mm. in diameter), spiral springs which shall present the outline of truncated cones (See Fig. 57 a), and fit inside the larger tambour pans.

If the student be supplied with tambour pans, spring, "rubber dam," thread, sealing wax and cork, he may construct his receiving tambour by placing the spring in the

tambour pan, stretching the sheet rubber over the spring, tying and sealing. The now conical diaphragm of the receiving tambour should be provided with a cork button, and adjusted by passing its tube through a horizontal hole near the end of one of the wooden rods (see Fig. 18). Connect the tambours by means of a small rubber tube.

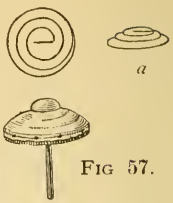


Fig 57.

11. The thoracometer.

If one wishes to measure the extent of the movements of the thoracic walls the stethograph, for mechanical

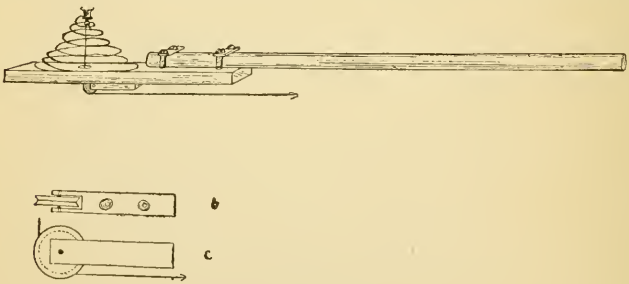


Fig. 58.

Fig. 58. Receiving button for Thoracometer—an instrument for use in quantitative determination of variations in thoracic diameters.

reasons too apparent to need enumeration here, affords, in the height of the recorded waves, unreliable data. To make a quantitative determination of the variation of any diameter of the thorax requires the application of a different principle. The following method has been successfully used: Construct the apparatus shown in the accompanying cut, using for the spiral spring brass wire 1.5 to 2 mm. in diameter. The cone defined by the spring should be 6 or 7 cm. across the base and should have an altitude from the base to the contact surface of the hard rubber

button of about 4 or 5 cm. It may be fixed to the hard wood or fiber base with three staples and the base in turn fixed, as indicated in the figure, to an iron rod about 1 cm. thick by 30 cm. long. A hole is bored through the base in the middle of the cone. A pulley whose plan and elevation are given in Fig. 58 b and c, fastened to the under surface of the base serves to change the direction of a cord which is tied to a ring in the hard rubber button.

12. The belt-spirograph.

The apparatus here described was contrived to overcome as far as possible the objections which may be raised

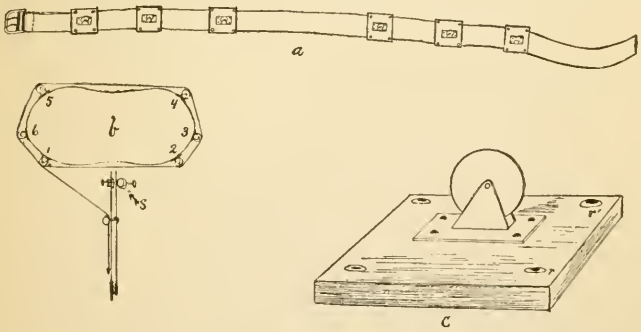


FIG. 59.

FIG. 59. The Belt-spirograph for quantitative determination of variations in chest girth.

to the previously used instruments for this purpose. Note in the first place that the wide elastic belt will follow faithfully every movement of the chest wall, not sinking into the soft tissues during inspirations; second, the almost inelastic fish cord will transmit the movement of the thorax much more accurately than elastic air inclosed within elastic conductors.

The 59 a, b and c figures show the construction of the belt spirograph: (a) The 2–3 cm. wide, elastic belt

showing location of pulleys. (b) A section of thorax showing belt in position. The cord is tied to an eye in pulley No. 1, passes around the circuit of pulleys to No. 1 again, thence over two or three pulleys which serve to change the direction, bringing the cord finally to a recording lever adjusted as described for the thoracometer. (c) Showing an enlarged view of a pulley. The brass base of each pulley is fixed to a piece of sole leather 4 or 5 cm. long by 3 or 4 cm. wide. Copper wire, riveted at the points r and r′, clasps the elastic belt and holds the pulley in position.

13. The stethogoniometer.

Various methods have been employed for determining the curvature of the chest wall. Even so simple a method

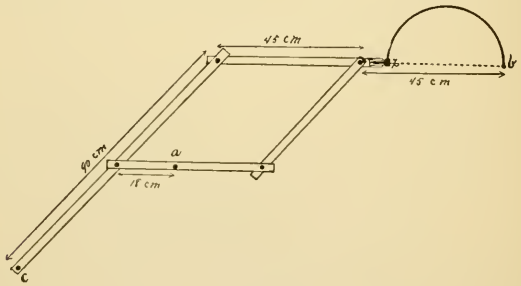


Fig. 60.

Fig. 60. The Stethogoniometer used in graphically recording any perimeter of the thorax.

as the taking of several diameters will reveal approximately the general conformation of the chest wall. A graphic method has this to recommend it : that a glance at an outline of any circumference of the thorax reveals more than any amount of time expended in the study of numerical data. Of all the graphic methods used by the writer the one here described seems most simple and practical. The accompanying figure (Fig. 60) shows the instrument, which will be recognized as similar to a draftsman's pan-

tograph. As used by the draftsman such an apparatus enlarges figures by any multiple from 1 to 5 in linear dimensions, for that purpose the tracing stilus is placed at *a* and the recording pen or pencil at *b*, while the point *c* is fixed to the table. As used to trace the curvature of any line in the body, the recording pencil is fixed at *a*, while the point *b* is made to follow the curved surfaces under observation. In this way records of one-fifth the linear dimensions of the curve traced may be recorded. Such records are compact and readily filed for subsequent reference.

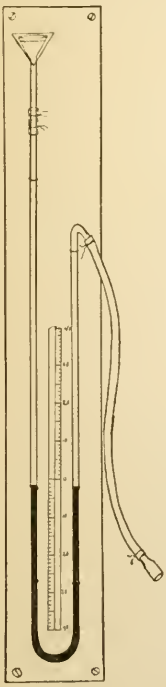


FIG. 61.

The Pneo-manometer. For testing pressure in forced respiration.

14. The pneo-manometer.

This instrument may be easily constructed in the laboratory. Take a piece of heavy glass tubing of 7 to 9 mm. lumen and at least 160 centimeters in length. Bend it as shown in Fig. 61. A covered filter may be attached as shown in the figure if there is any tendency for the mercury to be thrown out.

15. The chronograph.

For many experiments, especially upon the circulation or respiration, it is necessary to trace upon the rotating drum, along with the record of the circulatory or respiratory movement, a record of time in seconds or known fractions thereof. Instruments for this purpose are to be had from the instrument houses.

If the student or demonstrator is inclined to construct his own chronograph the accompanying figure and description may be of assistance to him. (See Fig. 62.)

Materials and Construction.—(1) A *soft iron* electro-magnet (m) with *soft iron* armature (a), as shown in A. A machinist or electrician can construct these from strictly pure, soft Swedish iron.

(2) No. 24 double silk covered copper wire, to be wound as indicated in A (x to y). The wire should be wound in three layers and when the winding is complete it should present the appearance shown in Fig. 62 B, m′.

(3) From fiber board or from wood one may construct such a lever and magnet support, as shown in Fig. 60 B. The lever (l) is pivoted at f; the block a′ bears the armature; the counterpoise (w) may be adjusted

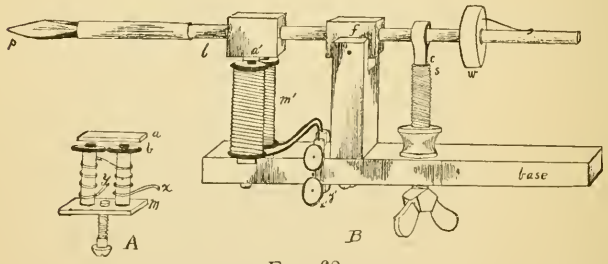


Fig. 62.

Fig. 62. The Chronograph.

so as to make the part of the lever at the right of f slightly heavier than that at the left, so that when no current is flowing through the electro-magnet the armature is lifted from the magnet.

(4) A check (c) rests upon an adjustable screw (s) and limits the excursion of the lever.

(5) A straw may be fixed with wax to the end of the lever and a tracing point (p) of parchment paper slipped into the straw.

(6) The wires from the clock or the chronograph system are connected at x′ and y′.

(7) The base may be clamped to a support and the tracing point adjusted to any height or direction.

This simple chronograph may be made sufficiently delicate to record $\frac{1}{5}$-seconds accurately, though seconds or half seconds will usually answer the purposes of the general experiment. For very small divisions of a second the tuning fork should be used.

To set up a simple chronograph.—Join the chronograph and the contact clock or a metronome in continuous circuit with a common Daniell cell. The clock makes contact every second or fraction, the armature is drawn down by the electro-magnet and thus records the time upon the drum of a kymograph.

16. The chronographic system.

If many students are working at the same time and at the same experiment in a laboratory, it is unnecessarily costly in both money and space for each student or group of students to be supplied with separate chronographic clocks and batteries. One clock and a battery of several cells can be employed to run ten or twelve chronographs. Such a chronographic system is too simple to require extended description.

(1) Bowditche's interruption clock or Petzold's simple contact clock may be hung in any convenient place in the laboratory and brought into circuit with

(2) A battery, *in series*, whose strength must depend upon the amount of external resistance to be overcome, i. e., the number of chronographs in the system.

(3) The chronographs must be all in one general circuit rather than upon branches from a primary circuit.

(4) A loop of the general circuit may pass to each table and the chronograph inserted in the loop. It is hardly necessary to remind the demonstrator that if,

for any purpose, a chronograph be removed from a table when the system is in operation, the general circuit must be instantly completed by use of a connector.

17. To prepare 10% hydrochloric acid, the acidum hydrochloricum dilutum of the U. S. P.

The concentrated, c.p., hydrochloric acid of a sp. gr. of 1.16 contains 31.9 per cent by weight of HCl gas. To prepare 10% HCl, take 31.4 c.c. of the concentrated acid and dilute with distilled water to 100 c.c. From this dilute HCl. 0.2% HCl or 0.1% HCl or any other desired strength below 10% may be readily obtained.

APPENDIX B.

APPENDIX B.

On the general plan of a course in physiology and the equipment of a laboratory.

The following pages are reprinted from a report of the committee on syllabus, representing the Association of American Medical Colleges. The committee was in session Feb. 15–18, 1896, Chicago.

The course in physiology.

The course in physiology should be continued through two years and should be, in a general way, coördinated with the course in comparative anatomy and general biology and histology. By coördination in this connection is meant the arrangement of the courses in such a way that the student shall learn first the more fundamental and general and then the more special. To teach the student the physiology of the liver one year and the gross and minute anatomy of that organ the next year must be recognized by all as an inversion of the logical order. To teach the anatomy of an organ one year and its physiology the next year puts the teachers of both these branches at considerable disadvantage, and the chances are great that the student will have a less clear comprehension of the subject presented in this way than he would if the interval elapsing between the study of the more general branch and the more special branch be a short one.

Every course in physiology should be accompanied by laboratory exercises in which the student may fami-

liarize himself with the technique of the subject and may demonstrate for himself the more fundamental facts of this science. The laboratory exercises should be coördinated with the recitations and demonstrations as far as it is possible to do so.

The first half of the first semester (eight weeks) should be spent in a study of the physiology of the cell as illustrated in unicellular plants and animals. While the student is studying the morphology of the protococcus, the yeast cell, the amœba and the paramœcium in the biological course he may profitably study the physiology of these organisms from such a text as, "The Cell" (Hertwig), and should repeat in the laboratory the experiments mentioned in Hertwig's book. "Allgemeine Physiologie" (Max Verworn, Jena, 1895) is a valuable help to the instructor who is conducting such a course.

The second half of the first semester may be spent on muscle-nerve physiology. Having already studied the reaction of amœba and paramœcium to electricity, and having studied, in general histology, the structure of muscle fibers and cells, and nerve fibers and cells; further having made careful dissections of frogs and other vertebrate animals the student is in a position to comprehend and appreciate the reaction of muscle tissue in response to various direct stimuli and to indirect stimuli applied to the nerve. The frog-heart and the "muscle-nerve preparation" are most used for such experiments.

Beginning with the second semester or second half of the first year the general subject of nutrition should be begun. Whether one introduces this field of physiology with the study of the circulatory system or of the digestive system is a matter of little consequence. The problems of the circulation being, for the most part, physical problems, would seem to justify the consideration of that sub-

ject first, followed by the respiratory system, which presents simple problems in mechanics, physics and chemistry. The student, having in the meantime made some progress in physiological chemistry, is able to comprehend the general features of the chemical problems involved in digestion, and should now enter upon a systematic consideration of nutrition: 1, food and foodstuffs; 2, preparation of foods; 3, mastication; 4, deglutition; 5, salivary digestion; 6, gastric digestion; 7, intestinal digestion; 8, absorption; 9, distribution; 10, assimilation or anabolism; 11, katabolism and animal heat, and 12, excretion. This course will probably consume the second semester of the first year and a part or all of the first semester of the second near. The remaining time allotted to physiology should be devoted to the physiology of the nervous system, the physiology of the special senses, and the physiology of reproduction. All of these courses should be accompanied by laboratory work.

After the student has completed the above required courses he should be given an opportunity to elect special courses in physiology during the second semester of the second year and during the third year. Profitable elective courses would be, for example: 1. Physiology of intrauterine life, following Preyer's "Physiologie des Embryos;" 2. Special problems in the physiology of digestion, following Brunton in "Handbook for the Physiological Laboratory;" 3. Physical examinations of the blood, using hematokrit, hemometer, corpuscle counter, micrometer and staining methods; 4. Experimental physiology of the central nervous system, following Cyon; 5. Physiological psychology, following Wundt or Ladd. The instructor may get much help from such works as Cyon's "Methodik der Physiol. Experimente;" Gscheidlen's "Physiologische Methodik;" Foster and Langley's "Practical Physiol-

ogy;" Schenck's "Physiologisches Practicum;" Brunton and Burdon-Sanderson's "Handbook of the Physiological Laboratory;" McGregor-Robertson's "Physiological Physics;" Langendorf's "Physiologische Graphik," and Stirling's "Practical Physiology."

The organization and equipment of the department of physiology.

Inasmuch as many of the colleges of the Association have not yet established physiological laboratories, it is thought well to give a few general hints on the subject. The imposing equipments which one sees in the physiological institutes of Europe, equipments which, in the aggregate, have cost many thousands of dollars, overawe one and make one hesitate to advise the undertaking of so great a task, so we are letting the years slip by without establishing physiological laboratories. We must not forget that the equipment of European laboratories is a growth which has covered many decades; and further, that it is really advisable to allow a department to grow, collecting, in the course of a few years, an equipment which is perfectly adapted to the wants of the institution and to the special methods of the head of the department. The committee strongly advises the early establishment of physiological laboratories, even if an institution cannot appropriate for the purpose more than $1,000 to start with. If an institution can devote to this department a well-lighted general laboratory room 36 ft. to 40 ft. square, with two or three small rooms for instrument room, workshop and library, and can appropriate $1,000 to $1,500 for the first equipment, then a laboratory fee of $5 annually from each student who works in the department will, in the course of a decade, produce a sufficiently full equipment for all practical purposes.

At this point it may be well to give a hint as to the organization of the department, as this determines largely the character of the equipment and the number of duplications of each instrument.

The amount of personal supervision required by the student in practical physiology is so great that it is inexpedient to attempt to conduct large classes. A demonstrator and one assistant demonstrator cannot properly supervise the work of more than thirty students at one time, even though each student be provided with a laboratory manual. In the organization and equipment here planned let it be understood that the laboratory class work in *sections* of thirty students each, and that each section be subdivibed into ten *divisions* of three students each. Now, experience in many laboratories has shown that a student will accomplish practically as much in one laboratory period of three hours as in two laboratory periods of two hours each. The three-hour laboratory period promotes economy both for the student and for the department. Following this arrangement, two instructors would be able to supervise the work of 180 students, meeting one section of thirty students each day. With this allotment of time each student would have three hours of laboratory work each week during the year, which would enable him to demonstrate for himself all of the fundamental principles of physiology. In the question of the choice between (1) the condensation of 180 hours of laboratory work in physiology into a period of sixty days with three hours per day, and (2) the distribution of the same number of hours over sixty weeks (two years) with three hours per week, and its coördination with theoretical work in physiology and with the courses in gross anatomy and histology, we would, without a moment's hesitation, decide in favor of the latter plan.

If this general plan of organization be adopted, and if the department wishes to provide for sections of thirty students, working in ten divisions of three students each, then the apparatus should be duplicated in tens. The following list of apparatus is suggested as a practical one with which to make a beginning: *

EQUIPMENT FOR GENERAL LABORATORY WORK.

10 strong tables, 6 feet by 3 feet, $5 00		$ 50.00
10 kymographs, $35		350.00
20 Daniell's cells, quart size, $1.75		37.50
4 pounds of copper wire, No. 18 double cotton cover, 50c		2.00
½ pound copper wire, No. 24 double silk cover, $2 00		1.00
10 simple compasses (for detectors), 30c		3.00
10 contact keys, $1.25		12.50
10 Du Bois keys, $3.25		32.50
10 simple rheocords, $2.50		25.00
10 Du Bois Reymond induction machines, $17.50		175.00
10 Pohl's commutators, with crossbars, $4.50		45.00
10 pairs of tambour pans, $2.00		20 00
20 heavy-base stands, $1.00		20.00
Fixtures for same—		
2 right angle clamp-holders, extra heavy	$0.50	
1 universal clamp-holder	0.75	
1 extension ring (4 inches)	0.25	
1 Muscle forceps, cork insulation	1.00	
1 simple myograph	2.50	
10 of each	$5.00	50.00
10 Bunsen burners, 35c		3.50
10 bell jars, 80c		8.00
10 double-valve rubber bulbs, large size, 50c		5.00
5 hæmometers (Fleischl's), $12.50		62.50
5 sphygmographs, $20.00		100.00
5 blood corpuscle counters (Zeiss), $17.50		87.50

*In reprinting the following list the author has taken the liberty to revise his earlier list as published in the report of the committee. As revised it provides for a higher class of apparatus at a proportionately higher price, but brings the aggregate down to the former estimate by reducing the number of incidentals.

General surgical appliances, forceps, shears, etc	25.00
10 pounds assorted sizes of glass tubing, 35c	3.50
Assorted sizes of soft rubber tubing	3.00
Rubber stoppers, assorted sizes, perforated	2.00
Corks and sheet cork	2.00
Cork borers, Files, for cutting glass tubing	2.50
2 gas generators, Kipp's, $3.50	7.00
Graduated cylinders, pipettes, flasks, bottles, beakers, etc	25.00
	$1,160 00

INSTRUMENTS FOR SPECIAL USE AND FOR DEMONSTRATIONS.

Detector	$ 2.50
Galvanometer	50.00
Rheostat or plug resistance box of 12 coils	10.00
Metronome, mounted to make and break circuit	12.00
Contact clock	25.00
Tuning fork, electrically maintained, mounted for tracing	25.00
Chronograph	10.00
Hæmatokrit	25 00
Plethysmograph	6.50
Quantitative balances	30 00
1 pair dog scales	15.00
Laboratory balances	10.00
Mercurial manometer for blood pressure	10.00
Ludwig rheometers	15.00
Moist chamber	20.00
Muscle forceps	3.50
Capillary electromometer (Kühne's)	5.00
Du Bois-Reymond rheocord	25.00
Hot air motor	40.00
Still for making distilled water	15.00
Drying oven, 10x12, double wall	13.00
Apparatus for determining focal distances	2 50
Steel-calipers	5 00
Spirometer	10 00
Stethogoniometer, belt-spirograph and pneomanometer	15.00
	$400 00

This list might easily be extended to amount to several thousand dollars, but it is intended here to include only those instruments which seem necessary to start with.

THE WORK SHOP.

Demonstrators and students can easily construct in a shop, many pieces of simple apparatus, which if purchased of some instrument house, would amount to many times the cost of the material and would deprive students of some very valuable experience. Frog, rat, rabbit and dog holders may be made, the tambour frames may be furnished with membranes and mounted as receiving or recording tambours, cardiographs, or stethographs. All writing levers, electrodes, etc., should be made by the students. A room with bench and vice and $25 for carpenter's and machinsts' tools would be an ample start.

A FEW NECESSARY CHEMICALS.

20 pounds $CuSO_4$	$ 1 40
10 pounds H_2SO_4	.75
5 pounds mercury	3.30
2 pounds kaolin (for electrodes, etc.)	.10
1 dram of curare	1.25
5 pounds gum damar	1.25
20 pounds benzol	4.00
10 pounds chloroform (imported duty free)	5 00
10 pounds sulphuric ether (imported duty free)	3 00
5 pounds unmedicated surgical cotton at 25 cts	1.25
2 pounds sealing wax in sticks	1.00
5 pounds plaster of Paris	.50
5 gallons alcohol (96%)	
1 gallon abs. alcohol	
2 pounds sodium hydrate	
2 pounds magnesium sulphate	
2 pounds sodium chlorid (pure)	
2 pounds glycerin	
1 pound hydrochloric acid	
1 pound nitric acid	
1 pound ammonium hydrate	
Drugs as listed under Pharmacology	
	About $35.00

A WORKING LIBRARY OF PHYSIOLOGY.

Beside the laboratory manuals enumerated under the "Course in Physiology," we mention a few journals and general works that should be in every laboratory of physiology: Hermann's "Handbuch der Physiologie"; *Journal of Physiology*, ed., Michael Foster, Cambridge, England; Pflüger's, *Archive f. d. gesammte Physiologie*, Bonn, Germany; *Archiv für Anatomie and Physiologie*, [physiol. part] ed., Du Bois-Reymond, Berlin, pub., Veit & Co., Leipsig; *Centralblatt für Physiologie*, pub., France Deuticke, Leipsic; *Journal of Experimental Medicine* [physiological part edited by Bowditch, Chittenden and Howell], D. Appleton & Co.; "Animal Physiology," Mills, D. Appleton & Co., 1889; "Text-book of Physiology," Michael Foster, Macmillan, 1888 93;" "Human Physiology," Landois and Stirling, Blackiston, Philadelphia, last edition; "Refraction and Accommodation of the Eye," Landolt, Lippincott, Philadelphia, 1886; "The Frog," Marshall, London, 1894; "Anatomy of the Frog," Ecker, Oxford, 1889; "The Cat," Mivart, Scribner, 1881; "Dissection of the Dog," Howell, Holt & Co., 1888; "Anatomie des Hundes," Ellenberger & Baum, Berlin, 1891; "Dictionary of Medicine," (4to), Gould, Blackiston, Philadelphia, 1895.

Beside these there should be recent representative manuals of histology, general biology, embryology, chemistry and physics.

PHYSIOLOGICAL CHEMISTRY.

It has been taken for granted that the chemical problems of physiology will be assigned to the department of chemistry. The equipment of that department makes such a division of the subject highly advantageous. For years urine analysis has been taught, usually in the second year of the course in the department of chemistry. Many of

the stronger institutions have long since expanded the second year course in chemistry into a very creditable course of physiological chemistry, beginning with an investigation of foodstuffs, following this with qualitative and quantitative work on the chemistry of digestion, and devoting the last semester of the second year to the analysis of urine. The best laboratory manuals on the subject are: Long's "Laboratory Manual of Chemical Physiology," Colegrove & Co., Chicago, 1895; Stirling's "Practical Physiology" (first part); Halliburton's "Essentials of Chemical Physiology" Longmanns, Green & Co., 1893. The physiological library should contain also: "Text-book of Chemical Physiology and Pathology," Halliburton, Longmanns, Green & Co., 1891; "Physiologische Chemie," Bunge, Vogel, Leipzig, 1894; "Lehrbuch d, physiologisch, Chemie," Neumeister, Gustav Fischer, Jena, 1893; "Physiological Chemistry," Hammarsten, Wiley & Sons, New York, 1893; "Physiological Chemistry of the Animal Body, "Gamger, Macmillan, 1893; "Chemical Physiology and Pathology," Hoppe-Seyler.

APPENDIX C.

APPENDIX C.

It is proposed at this point to devote a few pages to the illustration and brief description of the more important instruments and glassware which go to make up a practical equipment for a physiological laboratory.

1. Physical Apparatus.*

1. The Kymograph.—The basis of the instrumentarium of the physiological laboratory is the kymograph. It is in almost con-

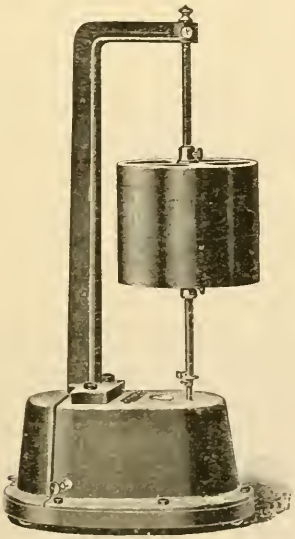


Fig. 1. Kymograph.

*For the plates in this section I am indebted to the Chicago Laboratory Supply and Scale Co., 29 West Randolph St., Chicago.

stant use in muscle-nerve physiology, in circulation, in respiration, and in pharmacology. It must be portable, durable, accurate, readily adjustable as to speed and height of drum. All of these qualities, together with reasonable cheapness, are possessed by the kymograph illustrated in the accompanying figure. This instrument was designed by Mr. C. H. Stoelting, of Chicago, for use in the physiological laboratory of the University of Chicago. It is now used in the University of Michigan, Northwestern University, Massachusetts Institute of Technology and the State Universities of Illinois, Texas and Colorado, in Rush Medical College, and the Detroit Medical College.

The height of the instrument is 55 cm.; weight 15 ko. The drum is propelled by a clockwork, which is under perfect control of the operator.

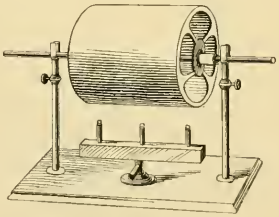


Fig. 1a.

Fig. a. Drum supporter with drum and burners.

2. The Myograph. *a*. The spring myograph, modified from Du Bois Reymond's. *b*. Simple myograph as used in the physiological laboratory of the Northwestern University, and shown in Fig. 2. *c*. The crank myograph.

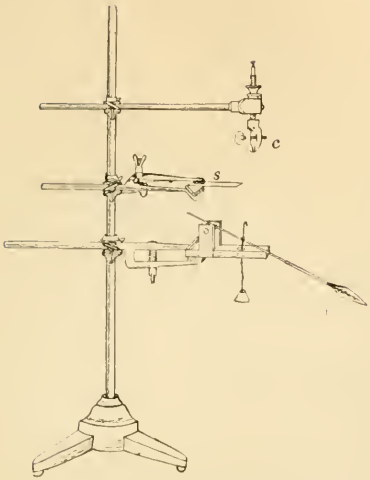


FIG. 2.

3. THE CHRONOGRAPH time-marker. Figure 4 shows Dr. Lingle's modification of Pfief's single chronograph.

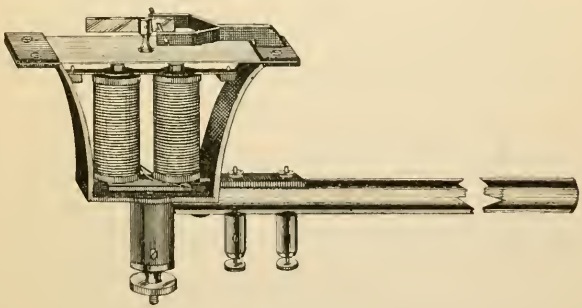


FIG. 3.

4. The Marey Tambour. See Fig. 4.

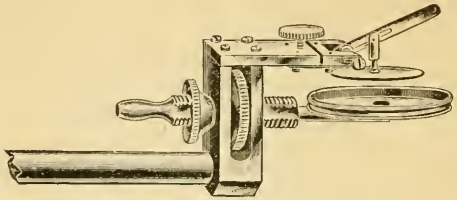


Fig. 4.

5. The Pohl Commutator. See Fig. 5.

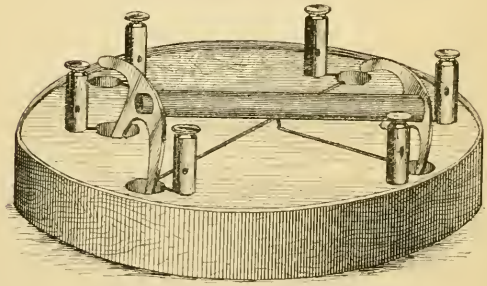


Fig. 5.

6. The Introduction Coil or Inductorium. Figure 6 shows DuBois-Reymond's instrumen). Ludwig's instrument consisted in changing the axia of the coils to the vertical position and counterpoising the secondary coil. The DuB-R. instrument, or some modification of it, is in more general use, and is satisfactory.

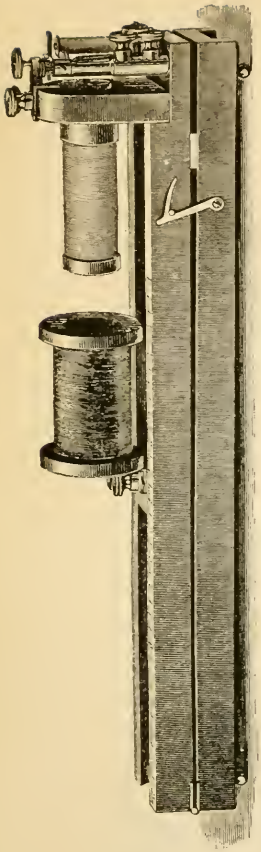


FIG. 6.



FIG. 7.

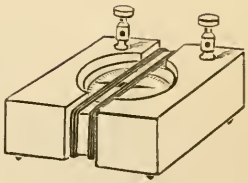


FIG. 8.

7. THE MUSCLE FORCIPS. *a*. Figure 8 snows a fine brass instrument with insulated jaws and a binding post. *b*. A simpler and cheaper form, with cork insulation, and without the binding post, answers all ordinary purposes.

8. THE DETECTOR, or low resistance galvanometer, is shown in Figure 8.

8a. THE GALVANOMETER, *a*, Eblemann's universal; *b*. Rosenthal's physiological.

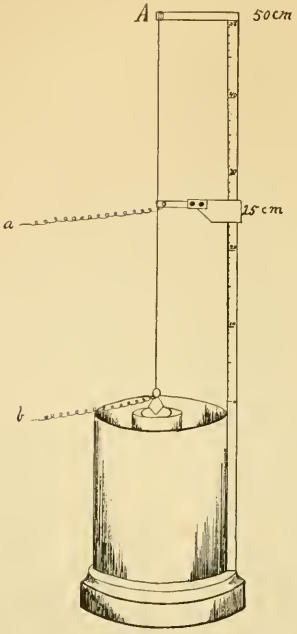


FIG. 10.

10. THE COMPENSATOR. Ludwig's instrument is shown in figure 10.

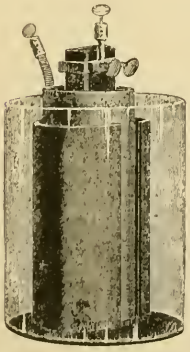


FIG. 11.

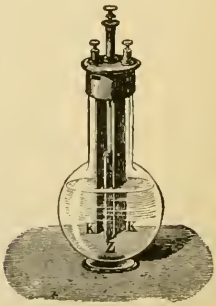


FIG. 11a.

11. BATTERIES. *a*. The Daniell cell, or element, is shown in figre 11. *b*. The Bichromate cell—see figure 11a.

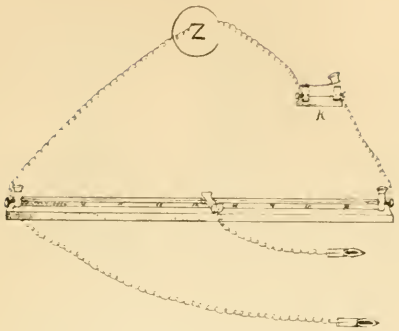


FIG. 12.

12. THE RHEOCORD. *h*. Dubois-Raymond's Rheocord. *b*. The simple rheocord as shown in figure 12. *c*. The Oxford rhecord.

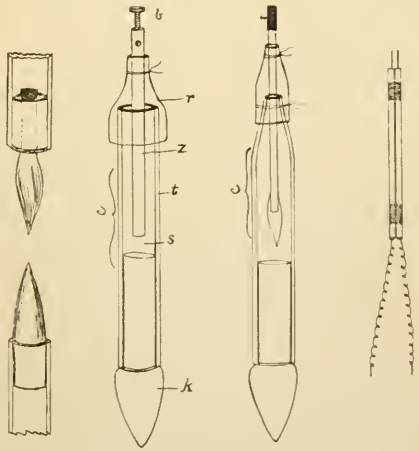


FIG. 13.

13. ELECTRODES. Figure 13 shows: *a*. *Hand-electrodes* of insulated copper or platium wires for use with induced currents. *b*. *Non-polarizable* electrodes, variously constructed. For description see text.



FIG. 14.



FIG. 14a.



FIG. 14b.

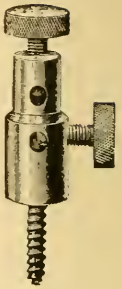


FIG. 14c.

14. BINDING POSTS. Various forms are shown above.

15. BINDING CONNECTORS. Constructed of brass and in varying forms.

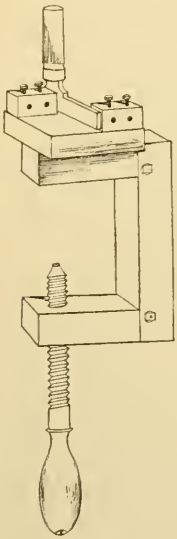


FIG. 16.

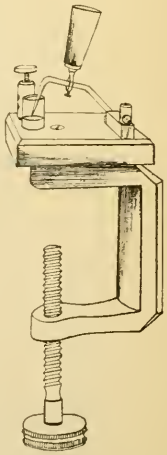


FIG. 16a.

16. KEYS. *a*. DuBois-Reymonds key with knife-edge contact. *b*. The mercury key, as shown in figure 16a. *c*. The spring contact key (Fig. 12K). *d*. The Morse key.

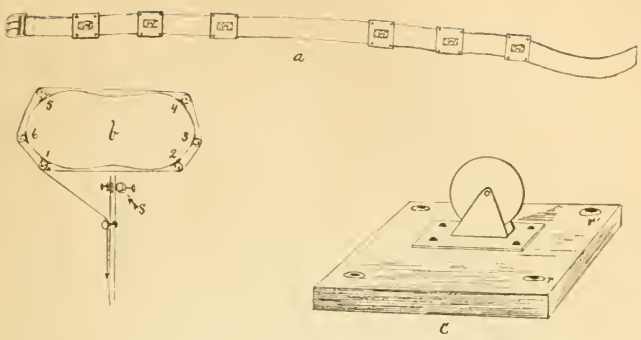


FIG. 17.

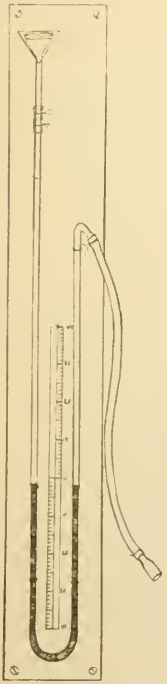


FIG. 17a.

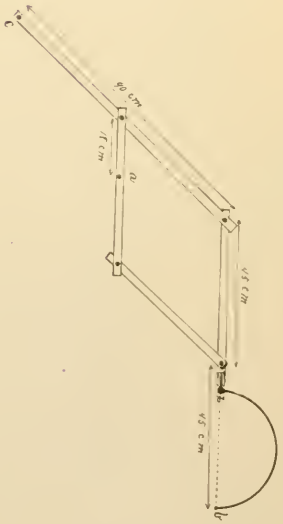


FIG. 17b.

17. ANTHROPOMETRIC INSTRUMENTS. These are various and consist of scales, meter tape, calipers, dynamometers, spirometer, etc., etc. Fig. 17 shows the belt-spirograph used to make a quantitative determination of variations of chest girth. Fig. 17a shows the pneo-manometer for testing forced respiratory pressure. Fig. 17b shows the stethogoniometer, for making a graphic record of the chest perimeter.

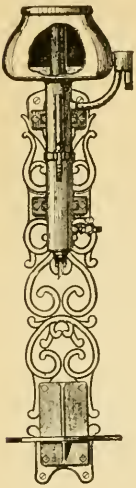


FIG. 18.



FIG. 19.

18. STILL. For making distilled water.

19. SUPPORT. Special pattern for physiology, with extra heavy base length 50–75 cm., weight 2¼ Ko.–4½ Ko.

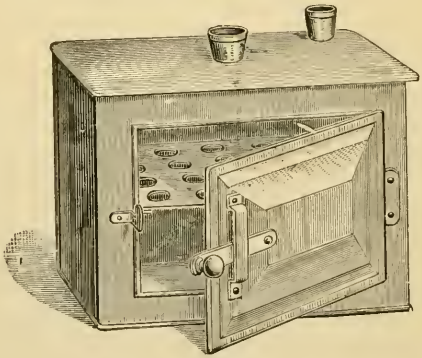


FIG. 20.

20. DRYING OVEN, with double wall 10 in. by 12 in. May be used for incubator in experiments in digestion.

II. Chemical Apparatus.*

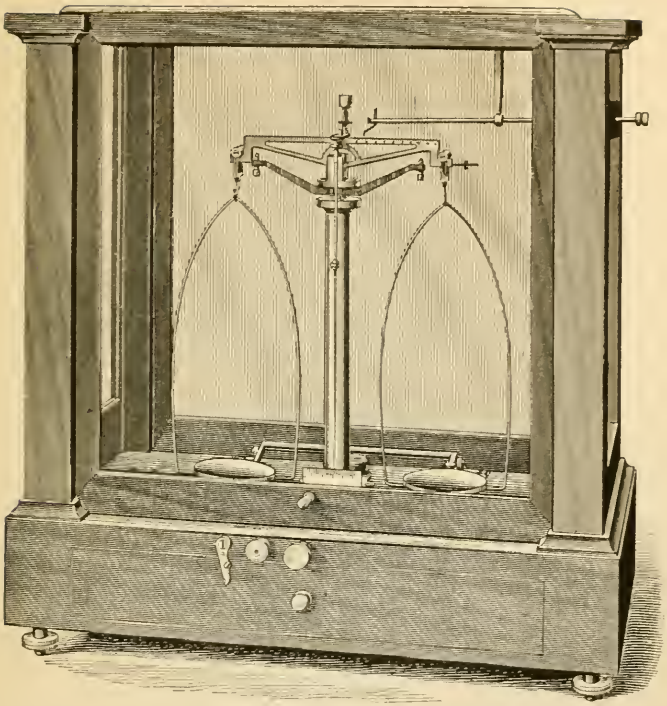


FIG. 27.

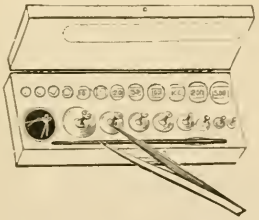


FIG. 28.

27. Analytical Balance, Becker's short beam, for a charge up to 100 g. in each pan. Sensitive to $\frac{1}{10}$ mg. with rider apparatus.

28. Analytical weight, Becker's, 100 g. down.

*For the plates in this section I am indebted to Richard & Co., 108 Lake St., Chicago.

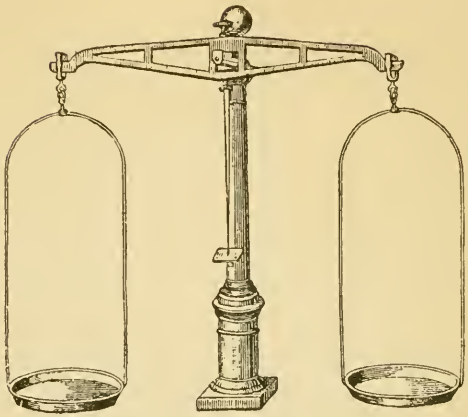


FIG 29a.

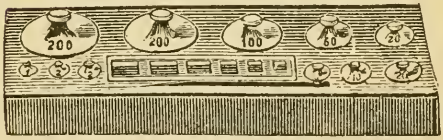


FIG. 29b.

29a. Balance for laboratory work. Capacity, 2 pounds. Sensitive to 1-20 grain.

29b. Weights 500 g. down, in polished block.

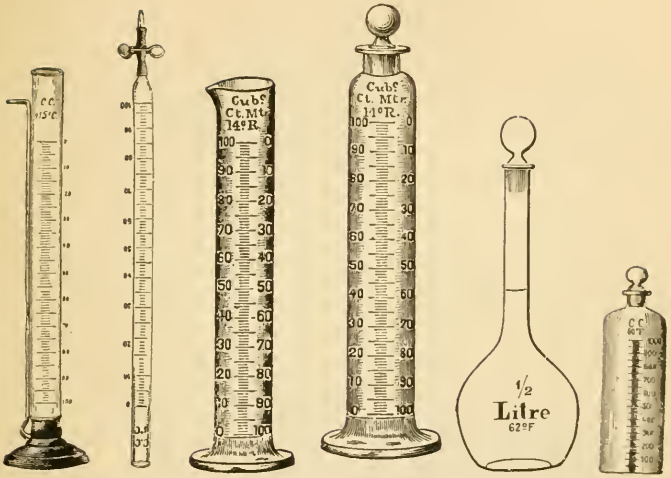


FIG. 30. FIG. 31. FIG. 32. FIG. 33. FIG. 34. FIG. 35.

30. Gay Lussac's burette, on wooden base, 25 c. c. in 1-10.

31a. Mohr's burette, w. pinchcock, 50 c. c. in 1-5.

31b. Mohr's burette, w. pinchcock, 100 c. c. in 1-5.

32. Graduated cylinders with lip, double graduation, 10 c. c., 50 c. c., 100 c. c., 250 c. c , 500 c. c., 1,000 c. c. and 2,000 c. c.

33. Graduated cylinders, stoppered, 100 c. c., 500 c. c. and 1,000 c. c.

34. Volumetric flask, 1,000 c. c.

35. Bottle for mixing, glass stoppered, 250 c. c., 500 c. c., 1,000 c. c.

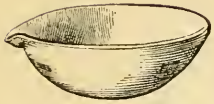


FIG. 36.

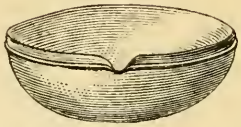


FIG. 37.



FIG. 38.

36. Evaporating dishes in nests of 9, from 2 oz, to 20 oz.

37. Evaporating dishes, best German porcelain, heavy rim, nests of five, from ¼ to 1 gal.

38. Flasks, vial mouth.

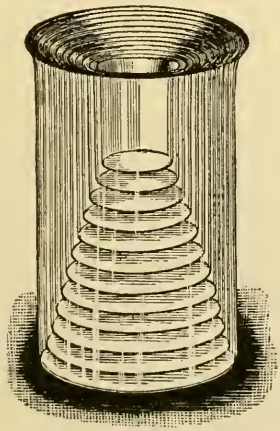


FIG. 39.

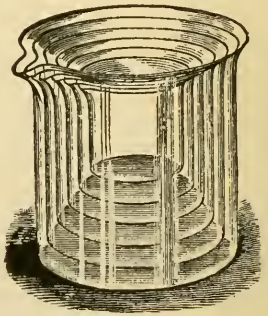


FIG. 40.

39. Beakers, plain 3 oz.-50 oz.

40. Beakers. Griffin, lipped, 5 oz.-64 oz.



FIG. 41.

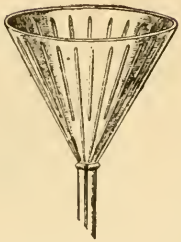


FIG. 42.



FIG. 43.

41. Glass funnels, best German, 2 in. to 8 in.
42. Glass funnels, ribbed, 3½ in. to 8 in.
43. Liter Erlenmeyer flasks, Jena glass.



FIG. 44.

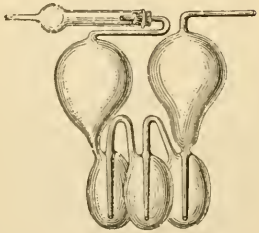


FIG. 45.



FIG. 46.

44. Calcium chloride tubes, Schwarz, 4-4.
45. Potash bulbs, Geissler's, with drying tube.
46. Woulf-bottles, 1 pint size and 1 qt. size.

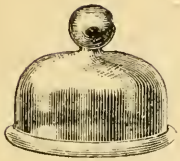


FIG. 47.



FIG. 48.

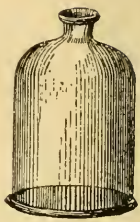


FIG. 49.

47. Bell glasses, low form, with knob, 6 in. diam.
48. Bell glasses, tall form, with knob, 7½ in. diam.
49. Bell glasses, open top, 6 in. diam.

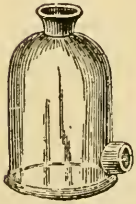


FIG. 50.

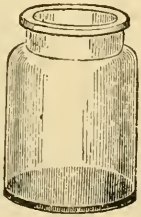


FIG. 51.



FIG. 52.

50. Bell glass, open top, with tubulure at side, ½ gal.
51. Bottles, extra wide mouih, 4 oz. to 16 oz.
52a. Bottles, mushroom, glass stopper, narrow mouth, 4 oz. to 16 oz.
52b. Bottles, mushroom, giass stopper, narrow mouth, 16 oz.

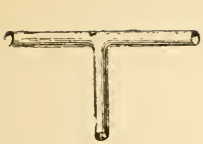


FIG 53.



FIG 54.



FIG. 55.



FIG. 56.

53. T-tubes.
54. Y-tubes.
55. Kipp's gas generator, 1 qt.
56. Thermometers, 150 degrees C.

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